THE
MATERIALS USED IN SIZING

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THEIR CHEMICAL AND PHYSICAL PROPERTIES, AND SIMPLE METHODS FOR THEIR TECHNICAL ANALYSIS AND VALUATION

A Course of Lectures delivered at the Manchester School of Technology

BY

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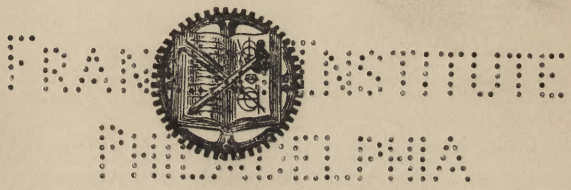

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PREFACE

In the early part of 1911 I was asked to deliver a course of lectures during the Summer Session of the Manchester School of Technology on "The Materials used in Sizing." In these lectures I confined myself to an outline of the chemical and physical properties of the commoner sizing materials employed in the textile industry, and to such methods of analysis and valuation as could readily be carried out by the Works chemist. Many requests have since been made to me for a book covering the subjects dealt with in my lectures, and this little work has been written to meet the desire so kindly expressed.

I have to tender my sincere thanks to Mr. Charles W. Gamble for assistance in the revision of the proofs, and to Mr. G. A. E. Schwabe for the trouble he has taken in preparing the illustrations which accompany the text.

W. F. A. E.

10, Marsden Street,
Manchester, 1912.

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INTRODUCTION

Before entering upon a description of the materials used in sizing, and of the methods used for their analysis, it will be advisable to consider shortly the mode of construction of a piece of cloth, and the reasons for the use of sizing. If a piece of cloth be pulled to pieces, it will be found to consist of a number of threads crossing each other at right angles. The threads running the long way of the cloth form the "warp," those running across the cloth are called the "weft." In order to weave a piece of cloth, the warp threads are placed in the loom evenly wrapped upon the "beam." The thread which is to form the weft is wound into what is known as a "cop," and this is placed inside the shuttle. The warp threads are led side by side from the beam through the "healds" to the roller at the front of the loom, to which they are fastened. When the loom is set in motion, alternate warp threads are respectively pulled up and down by the healds in such a way that the shuttle with its weft thread can be shot by the picker through the space between the upper and lower threads of the warp. A comb-like structure called the "reed" now pushes the weft thread, which the shuttle has left behind it, up to the point where the warp threads

separate. Then the healds reverse, pulling the upper layer of the warp threads down, and the lower layer up, so that the thread of weft is gripped between the two layers. The picker on the other side of the loom now shoots the shuttle back again between the threads, the reed presses the weft thread home—and thus the cloth is gradually built up at the rate of about 200 "picks" per minute, a speed which corresponds roughly to three inches of an ordinary shirting cloth.

It will thus be seen that the warp threads are subjected to a considerable amount of strain and friction in the weaving process. This is liable to cause frequent breakages, and also an undesirable degree of chafing or roughing up of the fibres of which the warp threads are composed.

It is in order to prevent this damage to the warp that the thread is almost invariably *sized* before being woven. The simplest method of sizing, and one practised from the earliest times, consists in passing the warp through a boiling starch or flour paste. It was soon found, however, that such a simple "size" made the yarn too stiff and harsh. It was liable to crack and break if at all sharply bent, and the healds were also very rapidly cut through. Hence, tallow or oil was added to the size, to give the requisite amount of softness and pliability. To these so-called "pure" sizes it became the custom to add a certain amount of mineral matter such as China clay or French chalk.

As the amount of mineral matter or loading increased, more fat had to be added to keep the yarn soft. But too much fat gives the cloth a greasy appearance; so that recourse was had to other softening agents, such as magnesium chloride or glycerine. These ingredients brought in their wake a fresh set of troubles in the shape of a liability on the part of the

sized goods to develop mildew. Consequently, a further set of ingredients, namely, antiseptics, have to be added to the "mixing," in order to prevent the destruction of the cloth by the mildew.

By a judicious combination of starches, fats, and mineral matters, it is now possible to add 200 per cent. or even more, to the weight of the warp, so that the cloth when woven may not contain more than 35 per cent. of cotton fibre. With the moral aspect of this question I do not propose to deal. It will suffice to regard a cloth as heavily sized or lightly sized, and to consider the nature of the "feel"—the quality and appearance of the cloth as it is influenced by the various ingredients which are used in the "mixing."

It will be apparent that the proposed ingredients of a sizing mixture must in the first place satisfy three demands:—

(1) They must be cheap.

(2) They must not act injuriously on the behaviour of the yarn during weaving.

(3) They must not give rise to defects in the cloth after it has been woven.

The materials used for sizing may be divided into five distinct classes, according to the purpose for which they are added. These are—

1. *Agglutinants.*—The function of an agglutinant is to hold together the individual fibres of the warp, rendering them less liable to be frayed and roughened by friction with the healds and reeds, and to strengthen them to resist rupture under the tension to which they are subjected by the movements of the mechanism of the loom. An agglutinant is used, in addition, to bind together the particles of clay or other mineral matter in the interstices of the yarn, and to prevent them from being shaken out either during or after manufacture. An agglutinant must be capable of dissolving in water, and the solution obtained must be of a

highly viscous character—almost pasty—so as to hold the mineral matter easily in suspension, and to allow of the mixture being readily taken up by the warp in the size box, and forced into the interior of the threads by the squeezing rollers. The materials used as agglutinants are—

Wheat flour.	Dextrin.
Farina.	Soluble starch.
Corn starch.	Iceland and Irish moss.
Sago.	Gum tragacanth.
Rice flour and starch.	Gum tragasol.
Tapioca.	

2. *Softening Materials.*—Since the starchy or gummy bodies mentioned above, when applied in a pure state to the warp, render the threads too stiff and harsh to be woven, it is necessary to add something that will give pliability and softness to the sized threads. The substances employed for this purpose are mainly of a fatty nature. But since any excess of these ingredients makes the cloth look greasy, it is necessary, where a high percentage of size is to be applied, to supplement their action by means of substances that keep the yarn soft by keeping it damp; in other words, hygroscopic substances. These have the further advantage of adding extra weight by virtue of this same moisture which they are instrumental in retaining.

The softeners of a fatty nature most employed are—

Tallow.	Paraffin wax.
Palm oil.	Japan wax.
Castor oil.	Spermaceti.
Cotton seed oil.	Oleine oil.
Cocoanut oil.	Soap.
Stearin.	

Softeners giving weight as well as softness are:—

Magnesium chloride.	Glycerine.
Calcium chloride.	Glucose.

3. *Antiseptics.*—Flour, which is one of the most common ingredients of a size, is a material excellently suited for the nourishment and growth of many forms of fungus or mildew. The spores of mildew are to be found everywhere, ready to spring into active growth as soon as the conditions are favourable, but are capable of lying dormant, though retaining their vitality, for an almost indefinite period in surroundings not suited to their needs. The conditions necessary for the germination of the spores on a suitable food bed are moisture and warmth. In a cloth sized with flour and softened with magnesium chloride we have two out of the three necessary factors. In a cold English warehouse, however, the temperature is usually too low for the spores; they remain dormant until the cloth is shipped to the East, where the temperature is much higher. The three conditions, foodstuff (flour), moisture (magnesium chloride) and warmth are all now present, so that when the goods are unpacked they are found to be in an almost unsaleable condition. In order to overcome this disastrous state of affairs, it is found necessary to make a further addition to the size—something that will act as a poison to the mildew spores and prevent their growth. Such poisons are termed "antiseptics." The antiseptic most frequently employed is—

Zinc chloride.

Other antiseptics, less frequently used are—

Zinc sulphate.	Salicylic acid.
Carbolic acid (Phenol).	Thymol.
Cresylic acid.	Formaldehyde.

CHAPTER I

THE STARCHES AND OTHER AGGLUTINANTS

General Properties.

The starches of commerce form white, glistening powders, odourless and tasteless.

They are insoluble in cold water, alcohol, chloroform, ether, and most other organic liquids.

Starch is very hygroscopic, and when dried at 100° C. may lose from 10 to 28 per cent. of moisture. This moisture is rapidly regained if the dry starch is exposed to the air at ordinary temperatures.

The starches are all chemically identical, being carbohydrates, of the formula $(C_6H_{10}O_5)_n$. Under the microscope, starch is seen to consist of minute granules, the shapes and sizes of which differ characteristically in the different starches. The granules are composed of concentric layers of starch cellulose alternating with layers of a substance known as granulose.

Granulose is soluble in water, but the starch cellulose is unaffected by cold water, and thus protects the granulose from its action.

If the cellulose layer is ruptured, the granulose absorbs water, swells to many times its original bulk, and finally goes into solution. The cellulose layers may be made to burst by the action of hot water, each starch having a definite temperature at which rupture of the granules take place.

Kind of Starch.	Temperature at which Swelling begins.	Commencement of Gelatinisation.	Perfect Gelatinisation.
Maize . . .	50° C.	55° C.	62·5° C.
Potato . . .	46° C.	59° C.	62·5° C.
Rice	54° C.	59° C.	63·0° C.
Wheat . . .	60° C.	65° C.	67·5° C.

The aqueous solution of starch may be prepared by adding boiling water to starch suspended in cold water, or the granules may be ruptured by grinding them in a mortar with sand, extracting the mixture with cold water, and filtering. The aqueous solution of starch, prepared as above, gives an intense blue colouration with a solution of iodine.

This colour is given by no other bodies but starch. On heating the colour disappears, but returns on cooling. Alkalies destroy the colour permanently, as they combine with the iodine. The blue compound of starch and iodine is insoluble in presence of neutral salts, and on this fact is based a method for the estimation of starch in solution.

Estimation of Starch.—A solution of starch, containing approximately one gramme per 100 c.c. is carefully neutralized. To 50 c.c. of this solution add 50 c.c. of a 10 per cent. solution of sodium acetate. Warm to 50° C. and add 10 c.c. of decinormal iodine solution. Allow to settle. Pour on to a dried and weighed filter paper, and wash with 3 per cent. sodium acetate solution till free from iodine. Wash the blue starch compound out of the filter with rectified spirit into a basin, and add a weak alcoholic solution of caustic potash drop by drop till colourless. Then acidify with alcohol containing a little glacial acetic acid, and return to the filter. Wash with alcohol on

the filter till neutral. Then wash twice with ether, dry in the water oven and weigh the residue of starch.

If a watery suspension of starch be stirred with a solution of caustic soda or potash, the granules gradually swell and burst, yielding a glutinous solution quite different in character from that produced by boiling a suspension of the same strength.

The author has worked out a method for the comparison of starches, based on this reaction (Vid. *Soc. Chem. Ind. Journal*, 1907, 501):—

3·5 grammes of starch are washed into a 250-c.c. graduated flask, with the aid of 230 c.c. of cold distilled water. 15 c.c. of exactly 10 per cent. sodium hydroxide solution are then rapidly run in from a burette, and the flask is filled up to the mark with distilled water and is shaken gently, but continuously, until the starch has gone into solution, after which it is allowed to stand for twelve hours. Finally, the viscosity of the solution is measured in a viscosimeter.

In order to obtain concordant results, the strength of the caustic soda solution should be exactly 10 per cent., as even a small variation will give a different viscosity. Every time that a delivery of starch is to be compared with the standard, solutions of both standard and delivery should be tested. The solutions should at all times be agitated as little as possible, and the solution that has run through the viscosimeter should not be used again. A small rise in temperature causes a considerable lowering of the viscosity; consequently care must be taken to ensure constant temperatures during the time of the tests. A strong solution of starch, prepared by means of caustic soda in which the alkali has been subsequently neutralized by the careful addition of sulphuric acid, is sometimes placed upon the market as a secret sizing preparation. At one time it was sold under the name of Apparatine.

If a solution of starch is treated at about 75° C. with a small amount of diastase or malt extract, it gradually liquefies, and becomes converted, first into soluble starch, then into dextrin, and finally, one-half of the starch is converted into maltose.

$$\underset{\text{Starch}}{3C_6H_{10}O_5} + H_2O = \underset{\text{Dextrin}}{C_6H_{10}O_5} + \underset{\text{Maltose.}}{C_{12}H_{22}O_{11}}$$

A somewhat similar change is produced when a starch solution is boiled with a small quantity of a mineral acid. The starch paste liquefies, and is converted into dextrin and finally to glucose.

$$\underset{\text{Starch}}{C_6H_{10}O_5} + H_2O = \underset{\text{Glucose.}}{C_6H_{12}O_6}$$

Identification of the Starches.—When starch is boiled with water, or caused to go into solution with the help of an alkali, the granules are ruptured, and it is impossible to state from which particular starch the solution was made. If the starch granules have not been attacked, they may be recognized under the microscope, and identified by their characteristic appearance and size. The granules of the same starch may differ widely amongst themselves in size, but in shape and general appearance they are very much alike.

The markings on the granules, which take the form of concentric rings surrounding a central dot or star-shaped crack, called the hilum, are very difficult to see clearly under the microscope by ordinary illumination. They should be viewed by polarised light.

In order to measure the diameter of the granules, a finely-ruled grating is dropped into the eyepiece of the microscope. The lines on the eyepiece micrometer are visible in the same plane as the object, so that the

apparent diameter of the granules can be measured against the spaces between the micrometer lines.

The real value of the eyepiece scale is then found by replacing the starch slide by one ruled in hundredths of a millimetre.

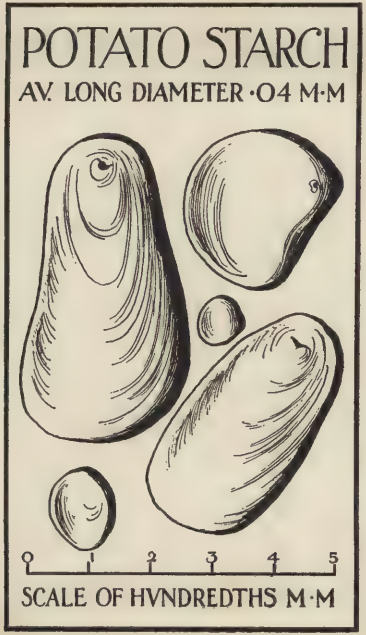
MICROSCOPIC CHARACTERS OF STARCHES.

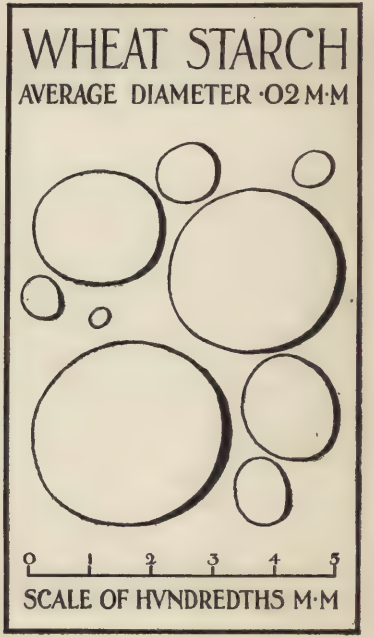
Origin.	Diameter of Granules.	Shape of Granules.	Markings and other Characteristics.
Wheat .	·002 to ·052 mm.	Lenticular.	Concentric rings very faint, hilum, eccentric: only occasionally visible in largest granules. Granules very transparent.
Farina .	·05 to ·1 mm.	Irregularly ovate; the smaller granules more circular.	Hilum a dot near smaller end. Rings visible on larger granules.
Sago .	·02 to ·06 mm.	Obtusely pear-shaped.	Hilum a spot or crack at narrow end. Rings few and faint.
Maize .	·007 to 0·2 mm.	Polygonal, but corners frequently rounded.	Hilum, well defined, star-shaped. Rings very faint. Surface granules frequently irregular.
Rice .	·005 to ·008 mm.	Irregular polygons.	Hilum and rings almost invisible.
Tapioca .	·008 to ·022 mm.	Some circular, some suggesting small sago granules.	Hilum central, an elongated slit, or star-shaped.

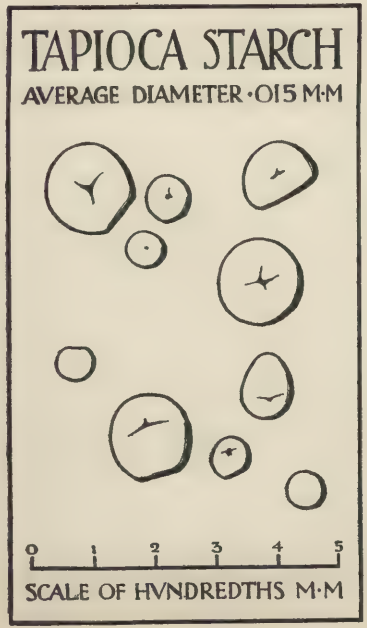
VALUATION AND APPLICATION OF THE STARCHES.

Wheat. — By far the most universally employed agglutinant is the starch derived from the wheat grain.


SAGO STARCH
AV. LONG DIAMETER ·035 M·M
0 1 2 3 4 5
SCALE OF HVNDREDTHS M·M


POTATO STARCH
AV. LONG DIAMETER ·04 M·M
0 1 2 3 4 5
SCALE OF HVNDREDTHS M·M


WHEAT STARCH
AVERAGE DIAMETER ·02 M·M
0 1 2 3 4 5
SCALE OF HVNDREDTHS M·M


TAPIOCA STARCH
AVERAGE DIAMETER ·015 M·M
0 1 2 3 4 5
SCALE OF HVNDREDTHS M·M


RICE STARCH
AVERAGE DIAMETER·004 M·M
0 1 2 3 4 5
SCALE OF HVNDREDTHS M·M


MAIZE STARCH
AVERAGE DIAMETER ·015 M·M
0 1 2 3 4 5
SCALE OF HVNDREDTHS M·M

It is generally purchased in the form of wheat flour, the average composition of which is :—

Starch	70	per cent.
Gluten	10	„ „
Glucose, Dextrin, Cellulose	9	„ „
Ash	·8	„ „
Moisture	10·2	„ „

For the valuation of different samples of flour, the points to be taken into account are —

Colour.	Quality of paste.
Moisture.	Freedom from other starches.
Ash.	
Gluten.	

Colour is best seen by placing a few grammes of the flour on a sheet of black glazed paper and pressing it out into a flattened heap. If heaps of two brands of flour are made in this way side by side, very small differences of shade become at once apparent.

The colour of the pastes made for the consistency test should also be compared.

Moisture is determined by drying a weighed quantity in a water oven until constant, and noting the loss in weight. As flour, especially when dry, is very hygroscopic, the watch-glass containing the flour should always be covered with another watch-glass during weighing.

Ash.—An ordinary flour never contains more than ·8 per cent. of ash. Hence any sample leaving more than this amount on ignition must be viewed with suspicion.

Any added mineral matter may be isolated from the flour as follows :—A weighed quantity of the flour (5 to 10 grammes) is poured into a dry separating funnel, about 150 c.c. of dry chloroform are then

added, and the mixture well shaken. After standing for an hour or two, all the flour will have risen to the top of the chloroform, whilst the added mineral matter will be found in the bottom of the funnel, from whence it can easily be removed by rapidly opening the tap, and further examined as to its nature.

Gluten.—Although this substance is frequently removed by fermentation before the flour is made into size, yet it is a very important index as to the value of the flour for size making. Gluten belongs to the class of nitrogenous bodies known as proteids, and contains nearly 15 per cent. of nitrogen. Hence it may be determined by Kjeldahl's method. Gluten$=N\times 6{\cdot}7$. Kjeldahl's method of analysis gives, however, no indication as to the quality of the gluten, and so should always be supplemented by the washing process.

With care this process can be made to give quite reliable quantitative results, and may, indeed, be used instead of the Kjeldahl method. Thirty grammes of flour are kneaded into a dough with from 12 c.c. to 15 c.c. of water. The ball of dough thus formed should be quite firm, and if properly made may be freely handled without sticking to the fingers. If any fragments of dough are seen adhering to the basin in which the flour was mixed, they can be wiped off with the main ball. The ball is allowed to lie on a glass plate for one hour. It is then tied up in a piece of fine muslin and gently worked about with the fingers in a large basin of cold water.

The water soon becomes turbid, owing to the starch that is washed out of the dough, and should be constantly renewed until it remains quite clear. The muslin is now untied, and when unfolded will be found to contain only the gluten of the flour. If the gluten is of good quality it will be light brown or straw coloured, whilst a poor quality will have a dull and dirty appearance. The good gluten will feel firm and

elastic. It can easily be rolled up off the muslin into a coherent mass. In this condition its elastic properties are very well marked. A bad gluten can only with difficulty be separated from the muslin. It tends to pass through the meshes and to fall away in fragments. The mass of collected gluten is crumbly and "short." It also frequently has an unpleasant odour, whereas a good gluten smells sweet, like a fresh "cottage" loaf.

The moist gluten separated from the flour as described, is weighed, and then dried in the water oven, and weighed again. The percentage of moist gluten found will vary from 5 to 40 per cent., and this on drying will lose about two-thirds of its weight. A flour containing about 30 per cent. of moist or 10 per cent. of dry gluten gives the best results in sizing.

Application.

Before being made into size, wheat flour is usually prepared by "steeping." The object of steeping is to loosen all the individual starch granules from one another, as even the finest flour contains numerous agglomerations of granules, which on boiling would form gelatinous lumps, and thus give rise to uneven places in the yarn.

The flour is stirred up in a large cistern with about its own weight of water, and the mixture left to itself for a length of time varying from three weeks to six months. In some works it is customary to run off the top layer of water after the first violent fermentation has come to an end. In other places the water is never changed.

No attempt is made as a rule to control the progress of the fermentation, although the character of the finished product depends largely on the co-ordinated activities of the different classes of bacteria concerned.

Control of the temperature during fermentation, and encouragement of the most useful organisms by the judicious supply of chemicals calculated to favour their growth, whilst checking the objectionable kinds, would amply repay the manufacturer.

Bean advocates steeping without any fermentation at all. He argues that since zinc chloride is almost invariably an ingredient of the final mixing, it may as well be added to the water in which the flour is to be steeped—at the rate of 4 gallons of zinc chloride at 102° Tw. to 25 gallons of water.

No bacteria or fungi can live in such a medium, consequently no chemical changes take place in the flour during steeping, and the final product is always the same, although of course it differs considerably from the product in which fermentation has been allowed to take place.

After the completion of the steeping process, the wet mass is stirred up with more water and run into the size beck, where it is boiled up and mixed with the other ingredients of the size.

Farina (*Potato Starch*).

Farina is obtained from potato tubers, 100 lbs. of which yield from 15 to 16 lbs. of dry starch.

The tubers are first carefully washed, and then rasped to a pulp from which the starch is separated by a process of sieving and settling. Some farina makers prefer to slice the washed tubers, after which they are piled into heaps and allowed to rot. The rotted pulp is then washed as above.

Deliveries of farina should be examined for the amount of *moisture* and *ash* that they contain.

The *colour* should be compared with that of the standard: and also the viscosity of the solution by the method given on p. 8.

A paste is made containing 7 grammes of farina in 100 c.c. of water. The stiffness of this is compared (by feeling) with that of a similar paste made from the standard. The two pastes are then allowed to stand covered up, side by side, and their behaviour noted. A good farina will gradually dry up, whereas a poor quality will partially liquefy and become mouldy.

The *moisture* may be determined by finding the loss in weight at 120° C., or by the method of Saare. He places 100 grammes of the starch in a 250 c.c. flask, fills with water at 17·5° C. and weighs.

Then the percentage of dry starch in the sample is given by the formula.

$$\frac{\text{Contents of flask in grams} - \text{capacity of flask in c.cs.}}{\cdot 3987}.$$

The moisture varies between 17 and 20 per cent.

The percentage of ash should be practically nil.

The sample should also be examined under the microscope. It should contain nothing but farina granules. Attention should be paid to the relative sizes of the granules.

In German farinas there is much less difference between the sizes of the granules than in Dutch farinas.

The paste made from a farina with regular sized granules is much more satisfactory than that made from farina with many-sized granules.

Whilst the former yields a warp that remains stiff for a long time, warps sized with the latter soon lose their stiffness, giving "soft beams," to which the weaver objects very strongly.

A size made from farina should be used up at once. It cannot be kept and warmed up afresh, as this warming up causes it to lose some of its adhesiveness.

The defect may be minimized by adding about 1 lb. of caustic soda to every 100 lbs. of farina.

Use of Farina in Sizing.

Farina size gives a characteristic smoothness and pliability to the warp, but owing to the stiffness of its paste it is used mainly for light sizing.

It finds some application in the very heaviest classes of sizings, where it is used in admixture with sago and corn starch.

Sago.

Sago starch is derived from the pith of various palm trees, the principal source of supply being the sago palm *Metroxylon Sago*. The tree grows in tropical low-lying marshes, where it reaches a height of about 30 ft. Just before the fruits begin to form the stem of the tree consists of a woody wall about two inches thick enclosing a dense mass of spongy cells filled with starch. If the tree is allowed to flower, all the starch is used up in the formation of the fruit, so that the palm is usually cut down just before maturity, the stem cut into sections, and the pith taken out and washed upon sieves in a similar manner to farina.

Sago should be examined upon delivery, for *moisture*, *ash*, *viscosity* of solution and *stiffness* of the 10 per cent. paste.

The *moisture* varies between 14 and 15 per cent.

If the sample contains more than a trace of *ash*, this should be examined for sodium chloride. Should this be found, it probably indicates damage by sea water.

Use of Sago in Sizing.

Sago yields a thinner paste than any other starch, and the paste is remarkable for the great strength it gives to the yarn. Moreover it does not tend to cause "soft beams" like farina. It is used for light and for

the heaviest sizings. For heavy sizes the starch must be boiled for a long time or the yarn will be too harsh.

·25 to ·5 per cent. of caustic soda may be added with advantage. Caustic soda deepens the colour, but where a full "Egyptian" tint is desired, this will not be an objectionable feature.

Maize, or Corn Starch.

Indian Corn (Zea Mais) when ground yields a nitrogenous flour, the average composition of which is as follows:—

	Per cent.		Per cent.
Starch	53·8	Fat	4·7
Gluten	8·2	Ash	4·8
Cellulose	13·4	Water	12·2
Gum and Sugar	2·9		

The starch is separated from the flour by treatment with very weak caustic soda or hydrochloric acid.

The action of these substances is sometimes supplemented by fermentation.

The pure starch contains about 13 per cent. of moisture, and less than 1 per cent. of ash.

Deliveries should be examined for *ash*, *moisture*, *colour*, *viscosity* and *thickness of paste*. The paste given by corn starch is characterised by being thick and opaque even when hot.

Use of Corn Starch in Sizing.

Corn Starch is seldom used alone in sizing, as it makes the yarn too harsh and brittle.

It is much employed for medium and heavy mixings, together with wheat flour, as it gives a harder and firmer feel to the cloth than wheat flour alone.

The starch must be well boiled before use, as it is

very apt to contain small agglomerations of starch grains and gluten. If these get on to the cloth unbroken, the gluten, being a good fungus food, may give rise to spots of mildew, whilst the rest of the cloth remains unattacked.

Size made with corn starch, like sago, does not readily liquefy, nor does it lose its strength-giving qualities when on the yarn.

Tapioca.

Tapioca is a prepared form of cassava or arrowroot starch. It is obtained from the roots of a tropical plant (*Manihot Utilissima*). Tapioca forms a pleasant and digestible ingredient of puddings and soups, but as a sizing material it is best avoided altogether. It gives a very thin paste, which rapidly loses strength, and, owing to the presence commonly of nitrogenous matters, is decidedly liable to give rise to mildew growths.

Rice Starch.

The rice plant (*Oryza Sativa*) has been cultivated from time immemorial in India and China, and the grain is largely used in those countries as an article of food. It is an annual grass, which occurs in many varieties, some growing best in swampy ground or in shallow water, others on dry hill-sides.

The ground seeds contain—

	Per cent.		Per cent.
Starch	78·2	Proteids	6·8
Fats	·7	Ash	·8
Cellulose	3·1	Water	9·9
Gum and Sugar	·5		

In order to separate the starch from the other ingredients, the grain is ground and treated with weak

caustic soda or hydrochloric acid. After the first treatment the product is dried, ground, and treated again in order to remove all the nitrogenous matter.

Use of Rice Starch in Sizing.

Rice is little used in ordinary sizing except to give a peculiar harsh feel to medium and heavy sized goods.

It requires prolonged boiling before it can be used. It is then generally mixed with about eight times its weight of wheat flour. It finds most employment in laundries, for the starching of cuffs and collars.

Soluble Starch.

Soluble starch is prepared from maize, farina or tapioca by a mild process of dextrination.

The usual treatment employed is to moisten the starch with very dilute nitric, acetic or formic acid and to dry carefully at 180° C. Sodium or calcium hypochlorite is also used.

It is very difficult to obtain a uniform product, even when the greatest care is exercised over the control of the operations. Consequently all deliveries should be very carefully tested against the standard.

The *moisture* and *ash* must be determined. But the most important test is the nature of the paste which the sample yields when mixed with water.

Ten to 20 grammes of the sample are stirred up with 25 c.c. of cold water, and 75 c.c. of boiling water added, with constant stirring. The mixture is then heated on a boiling water bath for a definite time, and the appearance of the solution compared with the standard, both when hot and after it has been allowed to stand covered overnight.

Soluble starch may also be prepared in solution by treating starch paste with diastase or malt extract.

The temperature and time of action must be carefully controlled. The action of the diastase can be stopped at any moment by raising the temperature of the mass to the boiling point or by rapidly stirring in a little alkali.

Use of Soluble Starch in Sizing.

Soluble starch is employed chiefly as a size for strong yarns where it is only necessary to lay the fibres, or where it is important that the colour should not be covered up, as it would be by the more opaque coating produced by a starch size.

A size made with soluble starch is not very adhesive, and gives little strength to the yarn, unless used in a very concentrated form. Further, the extra weighing can be much more cheaply obtained by means of a mixture of china clay and starch.

It is, however, employed to some extent for thinning down very heavy mixings.

Dextrin, or British Gum.

Dextrin is obtained from starch in the dry form by roasting it to 250° C. or by moistening the starch with dilute nitric acid, drying and heating to 150° C.

In solution it is obtained by acting on a starch paste with diastase, or by boiling with a mineral acid until the product no longer gives a blue colour with iodine.

Dextrin is sold as a powder having a characteristic odour, and varying in colour from white to brown, according to the amount of roasting to which it has been subjected. No hard and fast line can be drawn between dextrin and soluble starch. A highly-converted brown dextrin will contain about 83 per cent. of actual dextrin and 4 per cent. of glucose.

White dextrines closely resemble soluble starches, and have been so little acted upon in the process of manufacture that the starch granules are readily recognisable under the microscope.

Chemical Examination of Dextrines.

The *moisture* and *ash* are determined in the usual way. *Dextrin* and *sugar* are determined by shaking up a known weight of the sample with a definite volume of cold water, and allowing the mixture to settle. The dextrin and sugar go into solution, whilst starch and soluble starch remain undissolved.

A known volume of the clear solution is pipetted off, and evaporated to dryness on the water bath. This gives the weight of dextrin and sugar.

In another portion of the solution the *dextrin* is determined by precipitation with about ten times its volume of 95 per cent. alcohol. Ten cubic centimetres of the solution are introduced into a dry, weighed flask, and mixed with 100 c.c. of alcohol. The dextrin is precipitated, and after shaking and allowing to stand for a time, clots together and sticks to the walls of the flask. The alcohol can then be poured off and the contents of the flask dried and weighed.

A convenient way of drying the precipitated dextrin is that used by the author. The flask is closed with a doubly-perforated cork through which pass two glass tubes, one going nearly to the bottom of the flask. The longer tube is connected to the gas supply, and the shorter to a Bunsen burner. The gas is turned on, the Bunsen burner placed under a water bath and the flask in the water bath. Drying then proceeds very rapidly after the water has once come to the boil.

The proportions of *starch* and *soluble starch* may be confirmed by dissolving a weighed quantity of the

sample in boiling water and precipitating with iodine as described on p. 7.

An examination of the character of the solution formed by the sample should also not be omitted.

Fifty grammes are weighed out into a basin and stirred up with 100 c.c. boiling water. The solution is then stirred on a boiling water bath for a definite time, and its colour and appearance noted both when hot and after standing over-night. Care must be taken when adding the water to stir well, so that no lumps are formed.

Use of Dextrin in Sizing.—Dextrin finds only a limited application in sizing, and then it is mainly used in pure sizes, in admixture with farina or sago.

Gum Tragacanth (*Gum Dragon*).

Gum Tragacanth is an exudation from the stems of the various species of Astragalus trees growing mainly in Asia Minor. Formerly only the natural exudation was collected, but now the lower portions of the stems are "tapped" like rubber trees, the incisions being made near the roots. It occurs in commerce as tough, horny, twisted flakes, yellow or dull white in colour. It is tasteless and odourless, and is not acted upon by alcohol or ether.

When dried in a water oven, it loses about 14 per cent. of water; it becomes brittle and can then be easily powdered. When heated with water it swells up into clear gelatinous masses, which on prolonged boiling, go into solution, with the formation of a peculiarly ropy mucilage. Even a 3 per cent. solution is almost too thick to be poured out of an ordinary flask.

The solution is turned blue by iodine, owing to the presence of a small amount of starch. With caustic

soda it gives a deep yellow colour. It is precipitated by alcohol.

The analysis of a sample of gum tragacanth is restricted to a determination of the *ash*, and a comparison of the *viscosity* and *colour* of the solution with that given by the standard. To prepare the solutions the samples are dried in the water oven and finely powdered. Ten grammes of the powder are placed in a 500-c.c. flask, 250 c.c. of cold water are added, and the mixture well shaken until all lumps and air bubbles are removed. The flasks are then allowed to stand overnight. Next morning the contents are shaken up, and the flasks are kept for at least six hours in a boiling water bath, being well shaken from time to time to prevent the formation of lumps. Finally they are filled with boiling water, well mixed and allowed to cool. It is not advisable to fill the flasks up again to the mark, owing to the difficulty of evenly mixing the stiff solutions with more water.

Use of Gum Tragacanth in Sizing.—The material must be soaked overnight in cold water and then boiled with open steam until smooth, after which the solution is carefully strained from any small lumps that have failed properly to gelatinise and dissolve. Any such particles left in the size will cause trouble by sticking to the yarn and the rollers. They may also give rise to the local development of mildew. Gum tragacanth is not much used for sizing. Its cost is rather high and the preparation difficult. Also the feel produced on the cloth does not find favour amongst manufacturers.

Gum Tragasol.

This is a preparation made from the seed of the locust bean or carob tree, by the Gum Tragasol Company of Hooton. The cotyledons alone are used. Gum tragasol comes into the market as a thick, clear,

semi-gelatinous mass, light brown or white in colour, containing about 96 per cent. of water. It is neutral in its reaction, tasteless and odourless.

It is not directly soluble in water, but can be made to dissolve in any desired proportions by a special treatment. The required quantity of the gum is placed in a vessel fitted with mechanical stirrers and well stirred for about half an hour. Cold water is then added gradually, equal in amount to the gum taken. A thick syrupy liquor results, which is freely miscible with more water. The material is used in admixture with starches.

Iceland Moss.

Cetraria Islandica is a lichen with an erect foliaceous habit, giving it the appearance of a moss. It is of common occurrence amongst the mountain ranges of the North, particularly in Iceland. It is also found in North Wales and in Scotland. The thin, light grey sheets contain nearly 70 per cent. of lichenin, a body chemically very similar to starch, but without any granular structure.

Irish Moss (Carrageen).

This is a seaweed (*Chondrus Crispus*) which grows plentifully along the rocky coasts of Europe and North America.

It is collected, washed and dried and then forms horny, yellowish sheets, which contain about 55 per cent. of a mucilaginous body, 10 per cent. of albuminoids and 15 per cent. of mineral matter.

Use of Iceland and Irish Moss in Sizing.—The material is allowed to steep in warm water for twenty-four hours, after which it is boiled until dissolved, either with or without the addition of a little caustic

soda. A thick mucilage is formed with twenty to thirty times its weight of water, which has to be carefully strained from lumps before use.

Gelatine, Glue and Bone Size.

Gelatine, of which glue and bone size are impure varieties, does not exist as such in nature.

It is prepared by boiling animal tissues (horns, bones or hides), with water under pressure, when the collagen or ossein is decomposed, and goes into solution as gelatine.

The following analysis gives an approximation to the composition of ordinary gelatine :—

	Per cent.
Carbon	50·2
Hydrogen	6·7
Nitrogen	17·9
Oxygen	24·6
Sulphur	·4

"Pure" gelatine is an amorphous, transparent, brittle substance. It has no colour, smell or taste. When heated it softens and swells up, the decomposition products possessing a very disagreeable odour. The dry material is exceedingly stable, but when moist or in solution it undergoes putrefaction with great readiness.

In cold water *gelatine* swells up, absorbing from five to ten times its weight of water. The swollen gelatine melts at about 30°C. to form a more or less viscous liquid with great adhesive power. *Glue*, which contains a proportion of hydrolysed gelatine, or gelatose, at first swells up in water, but then the gelatose dissolves out, leaving a gelatinous or slimy residue, according to the purity of the sample.

On cooling, the solution gelatinises if it contains more than 1 per cent. of gelatine. But the gelatinising

power and adhesiveness are gradually destroyed by repeated heating or prolonged boiling. If a small amount of a soluble bichromate or formaldehyde is added to a dilute solution, the viscosity of the solution is increased, whilst stronger solutions are coagulated. After drying, the gelatine which has been treated with bichromate or formaldehyde becomes insoluble in water, and can only be made soluble again by prolonged boiling with an alkali. In the case of bichromates the insolubilising action is much hastened by exposure of the dried gelatine to light. Chrome alum has a similar effect to formaldehyde.

Gelatine is precipitated from its solutions by alcohol, being totally insoluble in 10 per cent. alcohol at 0°C.

It is insoluble in ether, chloroform, benzine, carbon bisulphide and oils. It is soluble in acetic acid, but the solution does not gelatinise on cooling.

Tannic acid also precipitates gelatine, but the precipitate formed is not of constant composition.

No precipitate is formed by gelatine on the addition of solutions of mineral or organic acids, or most metallic salts. It is, however, precipitated on saturation with ammonium, magnesium or zinc sulphate.

Isinglass is a particularly pure form of gelatine, made from the swimming bladders of certain fish.

Size is a very impure gelatine, usually sold in solution. It is obtained from gelatinous materials by boiling under pressure, after a previous treatment at a lower temperature for the extraction of high grade gelatine.

Valuation of Gelatine.—The colour, transparency and hardness of the sample should be noted. The solution in water should be neutral to litmus, and must not possess a disagreeable odour.

A weighed amount of the sample is allowed to soak in cold water for twenty-four hours. A bad sample will partially or wholly dissolve, whilst a good sample

will absorb from five to ten times its weight of water. When fully swollen, the fragments should be wiped dry and rapidly weighed.

Isinglass will yield on ignition about ·5 per cent. of ash, a good gelatine about 1·5 per cent. The ash from a glue is generally somewhat more than this.

A bone glue may be distinguished from a hide glue by the behaviour of its ash during ignition. The ash of a hide glue remains as a fine powder, whilst that from a bone glue fuses. The adhesiveness of a gelatine is measured by the viscosity of its solution. Thirty grammes are allowed to soak overnight in 200 c.c. of cold water. The swollen mass is then heated for a definite length of time on the water bath, and its viscosity determined at 35° or 40° C. After this constant has been determined, the solution is poured into a shallow basin and allowed to remain exposed to the air. A good quality of gelatine will soon gelatinise, and gradually dry up. A poor quality may gelatinise for a time, but it liquefies again after a few days, owing to putrefactive changes.

A good sample of gelatine or glue should be almost free from fat.

The amount of fat present may be determined as follows:—Twenty grammes of the sample are dissolved in 150 c.c. of water and 10 c.c. of strong hydrochloric acid. The solution is boiled under an inverted condenser for four hours (see Fig. 1), cooled and shaken up with petroleum ether in a separating funnel three times. The petrol is introduced into a dry weighed flask, and evaporated off on the water bath, when the fat remains behind and is weighed.

Use of Gelatine in Sizing.—The various grades of gelatine are used in sizing where a particularly hard feel is desired. Their use is to be deprecated, however, owing to the readiness with which even the best qualities give rise to mildew.

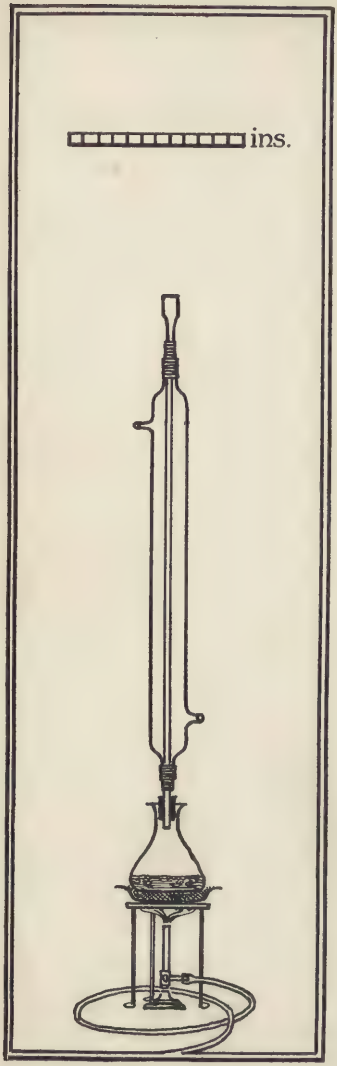


FIG. 1.

CASEIN.

Dried Casein, as met with in commerce, forms a white or yellowish powder. It is somewhat hygroscopic and swells up in hot water, but does not dissolve. It dissolves, however, in dilute alkalies, and in acids containing not more than ·1 per cent. calculated as hydrochloric acid. The solution in acids is precipitated by the addition of more acid, and on neutralisation with alkali. The alkaline solution is not coagulated on boiling, but is precipitated on the addition of salt, calcium chloride or magnesium sulphate. The precipitate will dissolve again in alkali after the metallic salt has been washed out. But if the precipitate is treated with alcohol it becomes permanently insoluble. If an ammoniacal solution of casein is poured upon a sheet of glass and allowed to dry, it forms

a transparent film which is quite insoluble in water, but dissolves slowly in alkali. If, however, lime is added to the ammoniacal solution, the film is no longer soluble even in alkalies. An alkaline solution of casein, on the addition of a little formaldehyde, remains clear if not too concentrated, but is coagulated by an excess of this reagent. The clear solution also leaves a transparent film on drying, which is, however, quite insoluble. Attempts have been made to utilise this property for the preparation of artificial silk, but hitherto without much success. The addition of casein to a sizing mixture produces effects resembling those due to gelatine. It is consequently not much used.

CHAPTER II

WEIGHTING MATERIALS

The ingredients most commonly added to a size mixing to give weight and body to the cloth are—

China Clay.	Barium Sulphate.
Epsom Salts.	Sodium Sulphate.
Calcium Sulphate.	

China Clay (Kaolin).

China Clay is obtained mainly from Devon and Cornwall, where it has been formed by the slow weathering of felspar. The crude clay is mixed with a large bulk of water, and separated into different grades entirely by settling. It is essentially a silicate of aluminium with the composition—

	Per cent.
Silica	45—47
Alumina	40—41
Water	11—12

The clay comes into the market as large crumbly lumps, which contain from 10 to 20 per cent. of moisture. This moisture can be removed at a temperature below 100° C. without altering the properties of the clay. The water which forms an essential part of the silicate molecule is only lost at a red heat, and its removal quite changes the physical properties of the clay.

The criteria by which a clay is valued are—

Feel.	Absence of Calcium Oxide.
Colour.	„ „ Iron Oxide.
Absence of Grit.	

The *feel* of a good clay cannot be described. The experienced man alone is competent to judge of this. Any difference between the feel of two samples is best detected by grinding equal weights of each with sufficient water to make a thick cream or paste. The pastes are then placed in watch glasses and pressed with the finger tips. The *colour* should be pure white, free from any tint of yellow, blue or grey. Samples to be compared are ground fine in a mortar, and made into little flattened heaps side by side on a sheet of black glazed paper.

Clays are frequently artificially coloured in order to make them a brighter white, or to mask a natural yellow tone. If the presence of colouring matter is suspected the clay is ground up with water to a thick cream, and four watch glasses are filled with this. A little caustic soda, acidified bleaching powder solution, and dilute hydrochloric acid are added to the contents of three of the watch glasses, and any alteration from the tone of the untreated portion noted. An alteration produced by caustic soda or chlorine denotes the addition of an artificial dyestuff; a change in the acidified sample the probable presence of ultramarine blue.

Grit is detected by placing some of the clay, mixed with water into a cream, between two sheets of glass, and moving them over each other.

A gritty sample should be at once rejected, as it will certainly lead to broken threads.

Calcium Oxide will be present as carbonate.

The clay is shaken up with dilute hydrochloric acid and filtered. The clear filtrate is neutralised with ammonia, and a little ammonium oxalate added. A

white precipitate of calcium oxalate denotes the presence of lime in the sample. This points either to careless preparation or to wilful adulteration.

Oxide of Iron.—China clay always contains a trace of iron, but a sample which has been stirred with a little hydrochloric acid, followed by potassium ferrocyanide, should only become tinted a light blue. A sample becoming deeply coloured should be rejected, as it may easily give rise to trouble in the subsequent process of bleaching. In order to make this test quantitative, equal weights of the clays to be compared are mixed with equal volumes of strong, pure hydrochloric acid and allowed to stand for one hour. They are then diluted with equal volumes of water, and a few drops of potassium ferrocyanide added. The colour produced is compared with that of a clay which has been washed free from iron, and has then had a known percentage of iron added to it.

The Use of China Clay in Sizing.

Clay is mixed with starch paste in the preparation of size mixings in order to give in the first place a certain desirable "feel" to the cloth. It has also the property of making a light and flimsily-woven cloth appear full and solid. It is cheap, and free from colour, so that it can be added to almost any extent that may be thought desirable. Before being made up into a mixing the clay is generally put into a mill, where it is agitated with boiling water for some hours. This operation is intended to break down all lumps and to separate the clay into fine particles. Bean is of the opinion that this operation would be much facilitated by first drying and grinding the clay to a fine powder. Clays differ so widely in the feel that they produce, that it is a sound rule for a manufacturer never to change his brand of clay

without very good cause. It is a matter of the greatest difficulty to match with a new clay the exact effect of a previous mixing.

EPSOM SALTS (MAGNESIUM SULPHATE. $MgSO_4.7H_2O$).

Magnesium Sulphate forms colourless crystals, which are readily soluble in their own weight of cold water. The only impurities that need be looked for are *iron oxide* and *magnesium chloride*. The solution should remain colourless on the addition of potassium ferrocyanide, and should give no precipitate of silver chloride on the addition of nitric acid and silver nitrate.

Magnesium chloride is frequently added to size mixings as we shall see later, but it is a dangerous substance, and is therefore better only added knowingly as such. If the Epsom salts are to be used for finishing, it is imperative that the chloride should be absent.

Epsom salts are used chiefly in ball sizing, and for mercerised yarns, where it is desired to add some weight without detracting from the appearance of the yarn.

GLAUBERS SALT (SODIUM SULPHATE. $Na_2SO_4.10H_2O$).

As a sizing ingredient this closely resembles magnesium sulphate in its application and properties. It should be free from iron salts, and neutral to litmus paper.

It may be noted that sodium sulphate should not be used in admixture with calcium chloride. These substances will react together forming chloride of sodium and insoluble, non-deliquescent calcium sulphate. As the addition of calcium chloride is made solely on account of its hygroscopic property, which is lost when the calcium chloride is converted into

the sulphate, it is clear that the character of the mixing would be entirely destroyed by the presence of any sodium sulphate.

Calcium Sulphate ($CaSO_4.2H_2O$).

Calcium Sulphate is a white crystalline powder almost insoluble in water, but readily soluble in hot, strong hydrochloric acid, from which it separates out again on cooling in the form of fine silky needles and lustrous plates. Two varieties are used in sizing.

That which is sold in the form of a dry powder is usually made by grinding the natural rock. Under the microscope it has the appearance of glassy plates and lumps very irregular in outline.

The impurities to be looked for are *iron oxide* and *calcium carbonate.*

The second variety is usually sold in the form of a stiff paste, containing about 30 per cent. of moisture. It has a more unctuous feel than the ground rock, and frequently shows a satin-like lustre. It is usually prepared by the precipitation of calcium chloride with sulphuric acid. Hence if the precipitate has not been properly washed it will contain either free acid or calcium chloride. It may also contain iron oxide.

Iron Oxide and *Calcium Chloride* are determined in the usual way, with potassium ferrocyanide and silver nitrate respectively.

To estimate the *free acid*, about 10 grammes of the sample are weighed into a flask, 100 c.c. of distilled water are added, and the mixture titrated with N/10 caustic soda, using phenol phthalein as indicator, 1 c.c. N/10 NaOH = ·0049 gr., H_2SO_4 = ·0017 gr. NH_3. When making the mixing, ammonia is added to the size in amount slightly greater than is equivalent to the quantity of free acid found. The ammonia should be added to the starch before the calcium

sulphate is stirred in, otherwise the free acid may begin to dextrinate the starch and thus upset the character of the mixing. Caustic soda or soda ash should not be employed for neutralisation, as these also affect the quality of the starch paste.

The amount of *moisture* in every cask of calcium sulphate must always be determined, as it is liable to vary considerably. About a pound of the substance should be taken from different parts of the cask and well mixed. From this about 5 grammes are weighed out and carefully ignited in a platinum basin until the weight is constant.

On ignition the water of crystallisation of the calcium sulphate is driven off, so that the residue is anhydrous calcium sulphate $CaSO_4$; and 136 parts by weight represent 172 of the crystalline solid in the form in which it exists in the paste.

The nature of the feel produced by calcium sulphate in a mixing depends to a considerable extent on the size and form of the crystals. These may be either large flat plates or fine needles. Care should be taken, by means of a microscopic examination, to see that each delivery is the same in this respect, as otherwise it will be impossible for the manufacturer to produce the same feel in his cloth with two different deliveries of the "mineral."

If a small amount of glue is added to the calcium chloride before precipitation, the calcium sulphate crystallises in the form of minute five-sided prismatic columns, but probably this form is not used by manufacturers.

Barium Sulphate ($BaSO_4$).

Barium Sulphate, obtained by grinding heavy spar, is sometimes used in size mixings. It produces a very harsh cloth, and has the objectionable property of rapidly wearing out the reeds and healds.

CHAPTER III

SOFTENING INGREDIENTS

As has been already explained in the introduction, starchy matters, either alone or in conjunction with mineral matters, produce a warp which is too stiff and brittle to allow of good weaving. Hence it is necessary to add something to the size that will counteract this tendency to hardness.

The most important substance used for this purpose is tallow. Other softeners less frequently used are—

Paraffin wax.
Cocoanut oil.
Olive oil.
Palm oil.
Castor oil.
Stearin.
Spermaceti.
Japan wax.
Soaps.
Magnesium chloride.
Calcium chloride.
Glycerine.
Glucose.

Tallow.

Tallow, on account of its high price, is very frequently adulterated. The additions most commonly met with are—

Water.
Mineral oils and waxes.
Bone and Marrow fat.
Cottonseed oil.
Stearin.
Recovered grease.
Starch.
Chlorides of sodium, magnesium and calcium.
Calcium carbonate.
Barium chloride.

There are two tests which should be applied to

every sample of tallow bought, namely, the determination of the *Saponification Equivalent*, and the *Iodine Absorption*, as these two tests will at once indicate the presence of any of the adulterants mentioned above, and will show what further tests are necessary in order to isolate the impurities.

Saponification Equivalent.

The *saponification equivalent* of a fat is a figure denoting the number of grammes of the fat that can be saponified by one litre of normal caustic soda solution. The term "saponification equivalent" must not be confused with the term "saponification value," which is another way employed by some writers of denoting the same property possessed by fats, viz., that of combining with alkaline oxides. The saponification value of a fat is the number of grammes of caustic potash required to neutralise 100 grammes of fat. This nomenclature is rendered rather more confusing owing to the fact that in some books the saponification value means the number of grammes of caustic potash required by 1,000 grammes of fat.

Thus the same value will appear in different works, as 20 or 200, which is equal to a saponification equivalent of 280.

To convert saponification equivalent into saponification value, we can make use of the formula—

$$\text{Saponification value} = \frac{5{,}600}{\text{Sap. Equiv.}}$$

or

$$\text{Saponification equivalent} = \frac{5{,}600}{\text{Sap. Val.}}$$

Whichever figure may be required, the determination is carried out as follows:—

We require accurately standardised normal hydro-

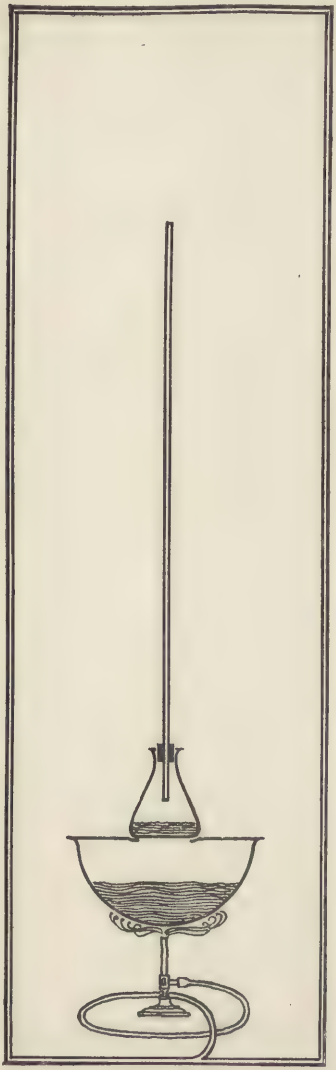


FIG. 2.

chloric acid, and an alcoholic solution of caustic potash about half normal in strength.

About two grammes of the fat are weighed out into a clean dry flask. To this is added 25 c.c. of the alcoholic caustic. The same volume of caustic is placed in a similar flask, and the neck of each is closed by a cork carrying a thin walled glass tube, about 30 inches long and $\frac{1}{2}$ inch internal diameter (see Fig. 2). The two flasks are then placed side by side on a boiling water bath. The flame under the water bath is so adjusted that the vapour rising from the boiling alcohol in the flasks condenses about half way up the tubes. The flask containing the fat is frequently shaken in such a way as to break up the melted fat into minute drops, as this allows the alkali to do its work more quickly. At the end of half an hour, the flask containing no fat is taken off

the water bath, phenol-phthalein is added, and normal hydrochloric acid run in from a burette until the red colour is just discharged.

Great care must be taken with this titration, as the phenol-phthalein gives hardly any warning as to the approach of the end point. The contents of the second flask are now titrated in the same way. Should the contents solidify before the titration is completed, a momentary immersion in the water bath will melt the soap jelly. As the same volume of caustic soda was used in both flasks, the difference between the amount of acid required by each flask is a measure of the caustic which has combined with the fat. If the strength of the acid is exactly normal, a simple proportion sum will give the amount of fat that would have neutralised one litre of normal caustic soda solution ; and this is the saponification equivalent.

If the saponification value is required, equally simple calculations will give us the number of grammes of caustic potash that would have been neutralised by 100 grammes of the fat.

The saponification equivalent of genuine tallow varies between 283 and 290.

Mineral Oils and Waxes have no action on caustic soda, consequently the presence of these substances will increase the saponification equivalent. For example, if we find that a sample of tallow gives a saponification equivalent of 320 we know that it takes 320 grammes of this particular tallow to neutralise one litre of caustic soda—an effect which 285 grammes of pure tallow can produce. Consequently, 320 parts of this sample contain 285 parts of tallow, the rest being unsaponifiable matter, paraffin. Therefore the sample contains 285 parts of tallow and 35 of paraffin, which is 10·9 per cent.

The next step is to isolate and weigh the unsaponifiable matter. We take the residue left in the fat flask

after titration, add a few drops of caustic soda, and distil off the alcohol on the water bath. The residue is then dissolved in about 100 c.c. water, and transferred to a separating funnel. Twenty-five c.c. of ether are added, and the funnel gently shaken. Hard shaking may produce an emulsion, from which the ether only separates very slowly. When the ether has formed a clear layer on the surface of the alkaline liquid, the latter is carefully run off into a clean flask, and the ethereal layer poured out of the top of the funnel into a dry flask. The aqueous layer is then returned to the separator, and treated twice more in the same way with fresh quantities of ether. After the third shaking the aqueous layer is thrown away, the ethereal portions returned to the separator, and shaken up twice with 100 c.c. of cold water. This is for the purpose of washing out of the ether a small quantity of soap which it always dissolves out of the aqueous solution, as well as the unsaponifiable matter. After being washed, the ether is poured into a dry, weighed flask, distilled off, and the residue of unsaponifiable matter weighed.

In the case of a tallow such as cited, with a saponification equivalent of 320, the 2 grammes of tallow should yield about ·2 grammes of unsaponifiable matter. An inspection of the residue will show whether it is paraffin wax, a mineral oil or the mixture of unsaponifiable oil and waxy alcohols derived from recovered grease.

Iodine Absorption.—The second important test to be applied to tallow is a determination of its iodine value: the percentage of iodine that the tallow can combine with under suitable conditions.

For this determination the following materials are required :—

Decinormal sodium thiosulphate solution.

10 per cent. potassium iodide solution.
Chloroform.
Wijs' solution.

Wijs' solution is made as follows:—13 grammes of iodine are dissolved in a litre of glacial acetic acid by the aid of gentle warmth. The solution is cooled, and 10 c.c. are pipetted out into a flask: 10 c.c. of potassium iodide solution, followed by 150 c.c. cold water, are added, and the mixture titrated with thiosulphate until colourless.

It is generally recommended to add starch solution during the titration of solutions containing iodine, but it will be found that the end point of the titration can be observed just as sharply by watching for the disappearance of the yellow colour. The change from yellow to colourless can be seen quite as well by gaslight as by daylight. When starch is used, the end point is frequently obscured owing to the presence of partially swollen starch grains, which become coloured blue whilst the iodine is in excess, and do not readily give up their iodine until the thiosulphate is considerably in excess. Hence the solution remains of a muddy purple colour even after the titration is actually completed.

About 50 c.c. of the acetic acid solution of iodine are now placed in a small dry flask. Into the remainder is passed a current of pure dry chlorine, until the colour of the liquid is suddenly observed to change from dark brown to light yellow. The current of chlorine is now interrupted, and another 10 c.c. of the liquor titrated as before with thiosulphate. The volume of thiosulphate required should be about double what it was for the first titration. If more than this is required, some of the original solution, which was put on one side before chlorinating, is added. If less than double the thiosulphate is

required, a little more chlorine is passed in. When the *titre* of the liquor has been adjusted so as to be just doubled, the operation is complete.

The chlorine for the preparation of the Wijs' solution may be produced by the action of dilute sulphuric acid on bleaching powder. (Fig. 3.)

The flask A containing about 30 grammes of

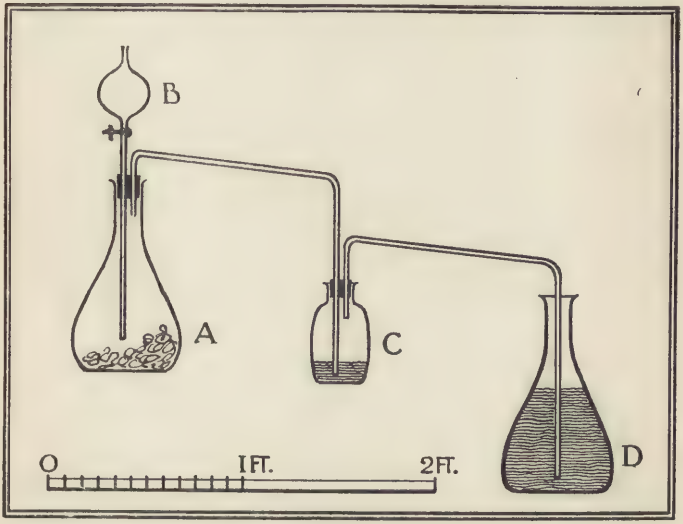


FIG. 3.

bleaching powder, is fitted with a doubly perforated cork.

Through the one perforation passes a tap funnel, B, containing 100 c.c. of 25 per cent sulphuric acid: through the other perforation passes a bent glass tube leading to a wash bottle C, furnished with pure sulphuric acid. The glass tube leading out of the wash bottle passes to the bottom of the flask D, containing the acetic acid solution of iodine.

Two clean, dry flasks are now prepared, and into one of them is weighed about ·2 gramme of the fat, followed by 10 c.c. chloroform and 20 c.c. of Wijs' solution. The same volumes of chloroform and of Wijs' solution are placed in the second flask. The two flasks are allowed to stand in a cool place, shaded from direct sunlight, for a quarter of an hour, and then titrated as directed above. When the liquid becomes colourless, it will probably be seen that the chloroform still retains some iodine, which has coloured it violet or pink. The contents of the flask must in this case be violently shaken—the mouth of the flask being meanwhile closed with a clean cork—and the titration continued, until both the aqueous and the chloroform layer no longer show any trace of iodine colour.

One cubic centimetre of thiosulphate solution is equivalent to ·0127 grammes of iodine. Hence the difference between the volume of the thiosulphate required by the blank and by the tallow flask, expressed in cubic centimetres, multiplied by ·0127 gives us the weight in grammes of iodine that has been taken up by the tallow or—

$$\frac{(\text{Volume of thiosulphate required by blank} - \text{volume required by test}) \times ·0127 \times 100}{\text{Weight of tallow taken.}}$$

The result gives the percentage of iodine absorbed, or the iodine absorption value.

For tallow this varies between 33 and 61.

A correct saponification equivalent and a high iodine value will point to the presence of *Cotton-seed oil*, as this has an iodine value of 102 to 111, with a saponification equivalent of 292. *Bone and marrow fats* will not be detected by either test.

Recovered Grease has a saponification equivalent of about 400, and an iodine absorption of only 7 to 28, so that not even a small addition can escape detection.

Mineral Oils and Mineral Waxes will have a still greater effect in the same direction, as they have neither iodine value nor saponification equivalent.

Starch will be detected during the determination of the iodine value, whilst *water and added mineral matters* are best found by the tests described below, although they will of course have already given signs of their presence during the carrying out of the determinations already mentioned.

Vaporisation Test.—In order to obtain quickly an idea as to the quality of a sample of tallow, Bean recommends the determination of the temperature at which visible vapours are given off. About 20 grammes of tallow are placed in a porcelain crucible resting on a sand bath, and a thermometer is suspended so that the bulb is covered by the tallow when melted. Heat is now applied from a burner under the sand-bath until the tallow begins to smoke, when the flame is removed, and the crucible watched until the vapours just cease to be given off, when the temperature shown by the thermometer is noted.

A pure tallow ceases to "vaporise" at a temperature varying between 125° and 160° C., whereas mineral oils vaporise between 80° and 110° C. Recovered grease, stearic acid and bone fat also show a low vaporising point.

Incidentally the test also serves to indicate the presence of water and starchy matters. If water or a soap solution has been added to the tallow, there is much crackling and spirting during the heating up, whilst starchy matters sink to the bottom of the crucible and are found there when the tallow is emptied out, as a partially charred mass which becomes sticky on the addition of water. The indications given by the vapourising test may be confirmed by a determination of the *flash point* of the sample. For this test we require a glass tube drawn out to a fine

point, and connected by a length of rubber tube to another gas jet. The gas is lit at the end of the fine tube, and turned down so that the flame is as small as possible.

The temperature of the tallow is now raised slowly and the little gas flame passed just over the surface of the tallow at short intervals until the vapours are seen momentarily to ignite with a small blue flash. With a good tallow, this first flash should take place at about 260° C. whilst the mineral oils generally used for adulteration flash at about 170° C.

Melting Point.—Pure tallow melts between 43° and 47° C. The addition of any notable proportion of mineral oil, bone fat or recovered grease will markedly lower the melting point.

In order to determine this temperature a piece of glass tube is drawn out into a capillary, and cut off where it

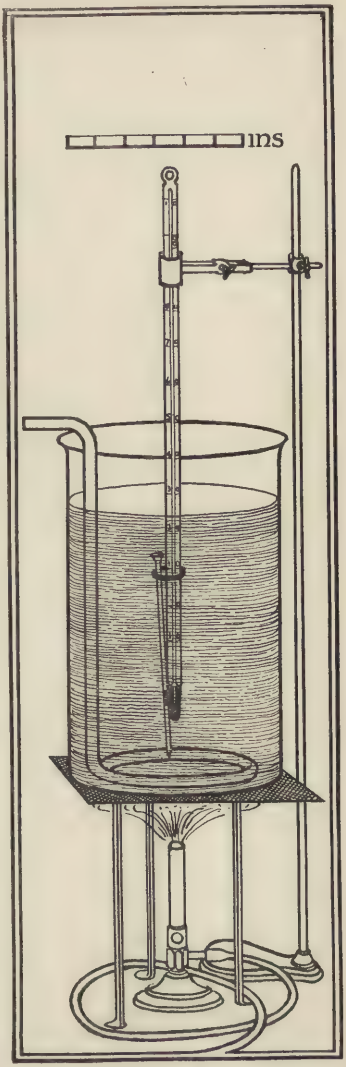


FIG. 4.

begins to widen in such a way as to leave one end funnel shaped.

A piece of glass rod is drawn out to such a thickness that it will just pass down inside the capillary. A fragment of tallow is placed in the funnel mouth of the capillary, and pushed down into the capillary proper by means of the thin glass rod so as to form a wad about $\frac{1}{8}$ inch long. The capillary is then sealed off about an inch below the tallow, and is fastened to the side of a thermometer so that the wad of tallow is held on a level with the bulb. A convenient way of fastening the capillary to the thermometer is to make a rubber ring by cutting a very thin section off the end of a piece of rubber tubing. The capillary is held in position alongside the thermometer bulb, and the rubber ring slipped over it and the thermometer. Capillary and thermometer are now suspended in a beaker of water, and the water is slowly heated, being at the same time kept well stirred. (See Fig. 4.)

Should air bubbles form on the thermometer bulb or capillary, they are best removed with a touch from a small paint brush.

As soon as the tallow is just melted to a clear liquid, the temperature of the thermometer is noted, and the flame removed. As the water cools, the tallow is carefully watched until it begins to turn cloudy, or crystals form in it, when the temperature is again noted. The mean between the two observed temperatures is the true melting point of the tallow.

It is sometimes recommended to fill the capillary tube by drawing up into it a drop of tallow which has been melted in a crucible. If this is done, the drop should be allowed to cool and to lie undisturbed for at least six hours before the melting point is determined, as otherwise too low a value will be obtained.

To prove the presence of bone or marrow fats, a few grammes of tallow are boiled in a dish with strong

hydrochloric acid for five minutes. These fats are always accompanied by a small amount of calcium phosphate, which is extracted by the hydrochloric acid. The aqueous layer is evaporated nearly to dryness, taken up with a little water and filtered. To the filtrate is added a slight excess of ammonia, when the calcium phosphate will be thrown down as a white precipitate. To confirm the presence of phosphate, the precipitate is redissolved by the addition of an excess of nitric acid, followed by the addition of a solution of ammonium molybdate. A yellow precipitate on heating indicates the presence of a phosphate.

Tallow which had originally a bad colour is frequently bleached by means of mineral acid; this should be very carefully washed out again by the tallow manufacturer. To test for mineral acid, the tallow is boiled in a basin for ten minutes with a little water. The water should remain quite neutral to methyl orange. If the methyl orange is reddened the amount of acid extracted can be titrated by means of 1/100 normal caustic soda.

1 c.c. of N/100 caustic soda is equivalent to ·00049 gramme of acid calculated as sulphuric acid. If the tallow contains any starch, this will also have gone into solution in the water; and its presence can be demonstrated by the blue colouration with iodine. Having now described the various adulterants that may be added to tallow, and the means for their detection and estimation, some consideration should be given to the question as to how these substances will effect the quality of the tallow.

Bone and Marrow Fat, Cotton-seed Oil and Stearine are nearly as good as tallow, as regards their softening effect. But they are all cheaper than tallow, so that their presence should not be tolerated if a good price has been paid for the tallow.

Starch, Soap, Water and *Soluble Chlorides* are much

more objectionable adulterants, as they reduce the softening value of the tallow considerably. Further, the chlorides of calcium or magnesium may give rise to serious injury if the cloth is to be bleached. They will cause tendering and discolouration in the singeing operation. They can only be regarded as harmless if the cloth is to be used in the grey state.

Paraffin Wax, *Mineral Oil*, and *Recovered Grease* are fairly good softeners. But they are not attacked by alkalies; consequently if the cloth has to be bleached or dyed, they are not removed by the scouring to which the cloth is subjected. They remain on the cloth in patches, and partially protect it from the action of the dyeing or bleaching liquors. The result is irregular stains and markings.

Paraffin Wax.

In certain cases this is quite a good softener. It is very seldom adulterated. The most suitable quality is that having a melting point of about 50° C. The melting point is determined in the same way as that of tallow (see p. 47). Paraffin wax, owing to the difficulty of completely removing it from the cloth, should never be used on goods which are to be bleached, dyed, or finished.

Bone Fat and Marrow Fat.

These fats resemble tallow very closely both in their softening power and in their chemical constants. They possess, however, a lower melting point, averaging 38° C. They frequently possess a very bad colour; but provided that this defect is absent there is no objection to using them in place of tallow.

Cocoanut Oil.

Cocoanut oil at ordinary temperatures is a white or cream-coloured solid, with a very characteristic

smell. It melts at 20° to 28° C. It is somewhat extensively used for certain classes of goods, mixed with Epsom salts. It is readily distinguished from other fats by its low saponification equivalent, 209 to 228, and its low iodine absorption, 8 to 9·5 per cent.

Olive Oil.

At the present time the price of olive oil is prohibitive. It is very frequently adulterated with cotton-seed oil or mineral oils. It has a saponification equivalent of 286 to 303, and an iodine absorption of 79 to 88.

Palm Oil.

Crude Palm Oil has a bright yellow or orange colour, and so cannot be used for ordinary size mixings. In its bleached state, however, it finds considerable favour. The most frequent adulterant is water, of which a large quantity can be mixed into the melted oil, without altering its appearance after it has congealed. Palm oil has a saponification equivalent of 277 to 286, and an iodine absorption of 48 to 54.

Castor Oil.

This oil is perhaps quite as good a softener as tallow. But it is not much used, as it is very liable to give the cloth a greasy appearance. The smell, too, is not altogether pleasant. Its saponification equivalent varies between 302 and 319; the iodine absorption from 83 to 85. Castor oil is remarkable in being the only neutral fat or oil which is freely soluble in alcohol.

Stearine.

Commercial Stearine is a mixture in varying proportions of stearic and palmitic acids. It should have a melting point of about 70° C. and a very low iodine

absorption. The saponification equivalent is determined by dissolving a known weight of the sample in hot neutralised alcohol and titrating with normal caustic and phenol phthalein. The figure given by a pure sample is between 285 and 293. Oily drops insoluble in alcohol, or a high saponification equivalent, point to the presence of paraffin wax, with which this substance is frequently adulterated.

Spermaceti.

Spermaceti comes into the market as a white waxy solid with a characteristic crystalline fracture. The melting point varies between 44° and 50° C., according to the amount of sperm oil present. It is frequently adulterated with stearine, tallow and paraffin wax. Its saponification equivalent is 437, and iodine absorption 0 to 10 per cent.

Stearine and tallow will be indicated by the lower saponification equivalent and raised iodine absorption. But if a judicious admixture of paraffin wax be added as well, this alteration of the values can be totally masked. Such a mixture, however, will lower the specific gravity of the wax. Spermaceti has the high specific gravity of ·942 at 15° C., whilst paraffin wax is only ·90.

In order to determine the *specific gravity* of a sample of spermaceti, a small piece, about as big as a pea, is carefully trimmed smooth, and placed in a cylinder containing either alcohol or strong ammonia. Water is then cautiously added, until the lumps of wax will remain floating in any part of the liquid. The liquid and the wax are now of the same specific gravity. The specific gravity of the liquid is then determined by means of the hydrometer.

The hydrometer is an instrument in the form of an elongated glass bulb, to which is affixed a thin cylindrical rod. The bulb is so weighted as to float

with the thin rod upright. The rod is usually hollow and contains a paper scale on which specific gravities are marked. These markings are so adjusted that the one at the surface of the liquid in which the hydrometer is floating, is the specific gravity of that liquid.

Spermaceti is much more expensive than any of the other softeners that we have considered hitherto, and it apparently fails to produce any effect different from that obtainable from a mixture of tallow and paraffin wax, so that the reason for its use as a softener is not very obvious.

Japan Wax.

Japan Wax, chemically, closely resembles tallow. It, however, contains very little olein, the ingredient that gives to tallow a high iodine absorption. The iodine absorption is only 4 to 6, the saponification equivalent 252 to 267. It is a hard yellowish or greenish wax melting between 51° and 54° C. It is not much used by manufacturers, but as it gives a feel very like that produced by paraffin wax, whilst, unlike paraffin wax, it is readily removed in the alkaline boil, it deserves a more extended adoption.

Table of Constants of Fatty Softeners.

Name of Fat.	Saponification Equivalent.	Iodine Absorption.	Melting Point.
Tallow	283—290	33—61	44°—48° C.
Bone and marrow fat	294	48—55	38° C.
Cotton-seed oil	292	102—111	—2° C.
Stearine	285—293	0	26°—31° C.
Cocoanut oil	209—228	8—9·5	20°—28° C.
Olive oil	286—303	78—88	2° C.
Palm oil	277—286	48—54	27°—42° C.
Castor oil	302—319	83—85	—17° C.
Spermaceti	437	0—10	44°—50° C.
Japan wax	252—267	4—6	51°—54° C.
Paraffin wax	∞	0	50° C.

Soaps.

Soaps form a very useful class of softening materials, when used knowingly as such, and not disguised under the name of "tallow substitute" or "patent softening."

Soaps are known either as hard or soft soaps. The soft soaps are the potassium salts of fatty acids, the hard soaps, sodium salts. They are usually made by boiling fats with a solution of caustic potash or soda, according as to whether a soft or hard soap is required. In the case of potash soaps, the quantities of alkali, fat and water are so adjusted as to give the finished article after a sufficient length of boiling. Soda or hard soaps are usually boiled with more water and a slight excess of alkali. When all the fat is saponified and has gone into solution, salt is added. This precipitates the soap, which rises as a granular mass to the surface of the liquor. It is removed and pressed into cakes, when it gradually solidifies.

When a soap solution is treated with an acid the soap is decomposed; the salt of the acid is formed, and the fatty acids of the soap liberated. Since 100 parts of fat yield 97 parts of fatty acid, the purity of a soap may be measured by determining the percentage of fatty acids yielded by the sample. An ordinary quality of hard soap should yield about 60 per cent. of fatty acids, a good soft soap about 40 per cent.

The fatty acid content of a soap may be determined in two ways. The simpler but less accurate method is that known as the "*Wax Cake Method.*"

Ten grammes of soap are dissolved in a 100 c.c. basin in 50 to 60 c.c. of water, heating on the water bath and stirring until solution is complete. An excess of sulphuric acid is then added, followed by exactly 10 grammes of beeswax or paraffin wax. The mixture is now gently boiled until all the liberated fatty acid has been taken up by the molten wax, and the contents of

the basin have become clear. The basin is now allowed to stand in a cool place until the layer of wax and fatty acid has solidified. The cake is then carefully lifted out of the basin, the acid liquor poured off and replaced by clean water.

The contents of the basin are next gently boiled again for a few minutes, after which the cake is allowed to solidify once more. It is now washed and gently wiped dry with filter paper. The basin is also wiped dry, taking care that no fatty material is removed. The cake is then melted in the dry basin, and kept hot for some while, in order to allow the last droplets of water to settle to the bottom. Finally, the cake is allowed to cool and weighed. The weight of cake, less 10 grammes, is the weight of fatty acid obtained from 10 grammes of soap.

A more elegant and accurate process is the extraction method. One to two grammes of the sample are carefully weighed into a flask. About 100 c.c. water are added, and the flask kept hot on the water bath until the soap has dissolved. The solution is cooled and transferred to a separating funnel, and is treated there with a small excess of hydrochloric acid. About 25 c.c. of ether or light petrol are added, and the mixture well shaken. The volatile solvent will take up most of the fatty acid after one shaking, and rises to a homogeneous clear layer above the acid solution. When the line of separation is sharply defined, the watery layer is carefully run back into the flask in which the soap was originally dissolved, whilst the ethereal layer is poured out of the top of the separator into a dry weighed flask. The acid solution is now returned to the separator, and the flask is rinsed, first with a little water, then with 25 c.c. ether or petrol, the rinsings being added to the contents of the separator. The mixture is once more well shaken, and the ethereal layer, after separation, added to the previous

portion. The extraction is repeated a third time, and then the ether or petrol is distilled off on the water bath (see Fig. 5), and the flask is dried and weighed.

I have alluded above to the use of ether or petrol. Ether is very expensive, but in the case of "olein oils,"

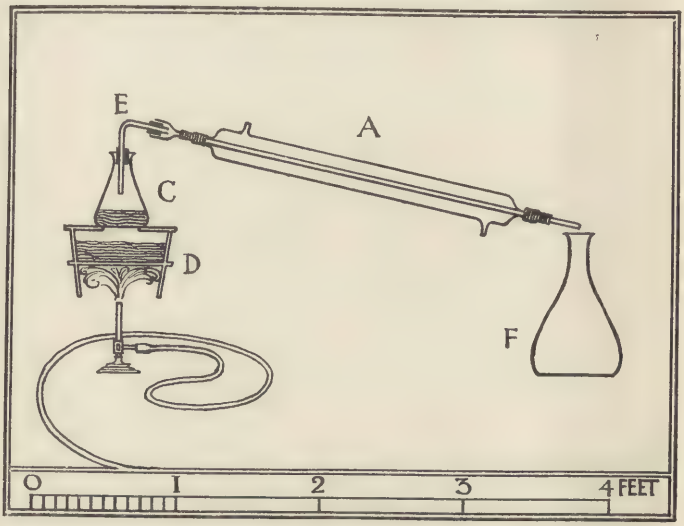


FIG. 5.

"soluble" oils, and olive oil soaps it must be used, as petrol gives too low a result. Where economy has to be studied the first two washes may be made with ether, and the third with petrol, as this has the property of recovering not only the last traces of fatty acid, but most of the ether as well.

In fat extractions the term "petrol" does not signify motor spirit, but the lighter variety known as Anglo's ·680 spirit, which is too volatile for engines, but

admirably suited for laboratory use. It cannot, however, be used exactly as bought, as it contains a small proportion of oils only volatile with difficulty. It is advisable, therefore, before use, to distil it on the water bath, and to reject the fraction remaining behind.

This distillation is much facilitated if a piece of thick string is fastened to the lower side of the cork closing the distillation flask, and of such a length as to reach just to the bottom of the flask. The heavy residue should not be thrown away, but should be preserved for cleaning out greasy flasks.

When determining the percentage of fatty acid in the class of soaps known as Turkey-red oil, soluble oil, oleine oil, or monopol soap, the solution should be saturated with common salt before adding the acid, since a portion of the fatty acids of these soaps is soluble in water, but insoluble in a strong brine. If this precaution is not taken the results obtained will be low. As I have already mentioned, these fatty acids have to be extracted with ether.

Ether always dissolves a little water, and this water is left behind in the distillation flask together with the fatty acids. These fatty acids soon decompose when heated in presence of water: they become discoloured, char and lose weight. To prevent this, as soon as all the ether has distilled over, the flask is placed in the boiling water bath and air is blown in until all the drops of water have disappeared. The flask is then at once cooled, wiped dry and weighed.

Free Alkali in Soap.

Soap is made by boiling fats with caustic soda solution, or fatty acids with sodium carbonate. If the quantity of alkali is not carefully adjusted to the requirements of the fatty bodies, or if the purification

of the soap is not conducted carefully, excess of alkali may easily be left in the finished product. Sodium carbonate and silicate are also frequently added to inferior soaps, as they enable the manufacturer to produce an article containing an undue amount of moisture, whilst still retaining the hardness generally associated with a high percentage of fatty acids.

It is very essential that a soap for use in sizing mixtures should be free from excess of alkali, since these would alter the properties of the starchy components.

The Determination of Free Alkalies in Soap.

The method used is based on the fact that sodium carbonate is insoluble in alcohol, whereas caustic soda and soap both dissolve freely. About half a litre of neutralised alcohol will be required for each analysis. This is made from ordinary methylated spirit, by adding phenol phthalein and then dilute caustic soda, until the alcohol is just pink.

Five grammes of the soap are weighed into a clean dry flask, and 100 c.c. of the neutralised alcohol added. The flask is then warmed on the water bath until the soap has entirely dissolved. The rest of the alcohol is meanwhile placed in a wash bottle, and brought to the boil on another water bath.

If the soap dissolves in the alcohol without any residue, it cannot contain any free carbonate or silicate.

If there is any free caustic soda present the red colour of the alcohol will have deepened.

Should there be any visible sediment, the alcoholic soap solution is filtered as quickly as possible through a small filter paper in a previously warmed funnel. As soon as nearly all the soap solution has run through, the filter is filled up with the hot neutralised alcohol.

The washing with alcohol is continued until all the soap has been removed. About 300 c.c. of alcohol will be required.

Soap is neutral to phenol phthalein in alcoholic solution, whilst caustic soda behaves just as it does in water. Hence the amount of free caustic in the alcoholic filtrate may be determined at once by titration with normal hydrochloric acid. Sulphuric acid must not be used, as the sodium sulphate formed is insoluble in alcohol. It will be precipitated as a white powder, and mask the end of the titration.

Filter paper always absorbs a small amount of caustic soda. Hence it may happen that a soap solution which was pink before filtration runs through the filter colourless. The amount retained, however, is so small that it may with safety be neglected and such a soap can be regarded as for all practical purposes free from caustic soda.

A soap may contain free fatty acid. In this case the original pink colour of the alcohol will be discharged as the soap dissolves. It is filtered and washed as usual, but is titrated with N/10 caustic soda, and the free acid calculated as oleic acid.

1 c.c. N/10 caustic soda = ·028 gramme fatty acid.

Any sodium carbonate present in the soap will be left on the filter paper. It is washed out with hot water, and titrated with hydrochloric acid and methyl orange.

Sodium silicate is slowly decomposed when boiled in alcohol into caustic soda and silica. The caustic soda goes into the alcoholic filtrate, the undecomposed silicate dissolves along with the sodium carbonate and is titrated as such, whilst the liberated silica remains on the filter as a colourless gelatinous mass, which may be determined by igniting the filter and weighing the residue of SiO_2.

Moisture in Soap.

A good hard (soda) soap should contain from 60 to 64 per cent. of fatty acids and about 30 per cent. of moisture. A soft soap will contain 40 per cent. fatty acids, and about 50 per cent. of moisture. Hence an idea as to the value of a soap can be obtained from the estimation of the amount of moisture present. The process for the determination of the moisture is carried out in the following manner :—

Into a dry 100 c.c. basin place about 25 grammes of clean dry sand and a glass rod. About 5 grammes of soap are then accurately weighed into the basin. To the contents of the basin are added about 50 c.c. rectified spirit, and the mixture is stirred constantly on a simmering water bath.

The soap will dissolve in the alcohol, and as this boils away it will carry with it most of the water that was in the soap. The pasty mixture of sand and soap must be frequently broken up with the glass rod to prevent the formation of any lumps. When the mixture has become dry and powdery, the basin with its contents is placed in an oven and dried at 105° C. until constant. The loss is water.

Use of Soap in Sizing.—Soap is freely used as a softener in light sizing. It must be borne in mind that soap reacts with Epsom salts and all other metallic salts, and consequently should never be added to a mixing containing these bodies. With Epsom salts the final products will be sodium sulphate and a magnesium soap. This, as well as the calcium and zinc soaps, is a colourless, sticky substance.

The metallic soaps are water repellant, and hence are not easy to remove when the cloth is scoured. The magnesium compounds, and especially that formed from soaps containing resin, have the further

objectionable property of slowly turning brown, owing probably to oxidation.

Deliquescents.

The third class of bodies added to size in order to keep the yarn soft are those whose activity is due to their power of absorbing moisture from the air, and thus keeping the cotton damp.

In light sizes such bodies are not required, as soap or tallow will do all that is necessary. But in heavy mixings the influence of these has to be supplemented by the addition of a deliquescent. The bodies used for this purpose are—

Magnesium chloride.	Glycerine.
Calcium chloride.	Glucose.

Magnesium Chloride ($MgCl_2.6H_2O$).

Magnesium Chloride is sold as a white crystalline solid, containing 46 per cent. of the dry substance, or as a solution containing 30 per cent. The commercial article is usually quite pure, but the following impurities should be looked for.

Magnesium and Sodium Sulphates.—These are objectionable, inasmuch as they are not deliquescent. Their presence is detected by the white precipitate of barium sulphate produced on adding a little hydrochloric acid, followed by barium chloride.

Sodium Chloride.—Common salt also lowers the deliquescent power of the magnesium chloride. Its presence in any quantity sufficient to be detrimental is detected as follows:—

The sample is mixed with twice its bulk of strong hydrochloric acid, in which sodium chloride is practically insoluble. Hence the method may be made quantitative. The precipitate is washed by decantation, with strong hydrochloric acid, until free from

magnesium. It is then transferred to a basin, the acid evaporated off on the water bath, and the residue weighed.

Calcium Chloride.—This is almost as good a deliquescent as magnesium chloride. It is objectionable, however, if soluble sulphates are to be added to the mixing, as it will react with these, forming insoluble calcium sulphate, and thus altogether alter the character of the size. To detect calcium, the sample is dissolved in water and mixed with a considerable proportion of ammonium chloride. Excess of ammonia is then added. If any precipitate of magnesium hydrate is formed, it should be redissolved by the addition of hydrochloric acid.

Ammonia is then again added, and the further production of ammonium chloride should keep the magnesium in solution. After the ammonia there is added ammonium oxalate. This will react with any calcium present to form a white precipitate of calcium oxalate.

Iron Compounds.—These will be present as ferrous or ferric chloride. The smallest traces are very objectionable, as they tend to break down irregularly into ferric oxide, after the warp is dried, with the formation of patches of "iron mould."

Magnesium chloride is an excellent softener, but its use is attended with considerable danger. When a solution of magnesium chloride is evaporated it partially decomposes. Hydrochloric acid is given off, and an oxychloride remains behind. Warps treated with a size containing magnesium chloride should be dried very carefully at a comparatively low temperature, so that the decomposition is minimised, and the yarn is not tendered.

When cloth is to be bleached, the first process to which it is subjected is that known as "singeing" or "firing." The cloth is drawn over a red-hot copper

plate, or between two rows of gas flames. If it contains magnesium chloride, it will certainly be tendered, if not altogether destroyed, by the high temperature to which it has been subjected. The remedy is simple. Before firing, the cloth must be washed and dried. The trouble arises when the manufacturer omits to inform the bleacher of the necessity of this preliminary wash.

At times the manufacturer does not know that he has used magnesium chloride. There are many preparations still being sold as "patent softeners," or "glycerine substitutes," the basis of which is magnesium chloride, mixed with dextrin or glucose.

Magnesium chloride cannot entirely replace tallow as a softener either in light or heavy sizing. It does not produce the same feel when used by itself. It should only be added as a supplementary ingredient.

But there is another objection to the replacement of the functions of tallow with too great a proportion of magnesium chloride.

Yarn sized in this way acts very energetically on any iron with which it may happen to come into contact; it induces a rapid formation of rust, and the rust so produced will be deposited in part upon the cotton, thus causing very unsightly iron stains, particularly when the looms are allowed to stand motionless for a while.

The erroneous opinion is still held by some manufacturers that magnesium chloride has antiseptic properties. Far from this being the case, magnesium chloride favours the growth of mildew. It not only provides moisture, without which the spores cannot germinate, but it also acts as a foodstuff for the spores when they have germinated.

Calcium Chloride ($CaCl_2.6H_2O$).

This substance is very similar to magnesium chloride in its properties. The crystalline preparation

is usually of sufficient purity to be used without any fear of untoward results. It is also sold in a fused condition, containing about 70 per cent. of the anhydrous substance. If purchased in this form, the material must be carefully tested for *free acid* and *iron oxide*.

Free acid will be liable to cause tendering of the yarn, and will also dextrinate the starch in the mixing, thus entirely altering its character.

The solution must be quite neutral to methyl orange, and must give no blue colouration on the addition of potassium ferrocyanide. Both iron and free acid are readily removed by adding slaked lime to the solution until it no longer reddens methyl orange. The excess of lime and any precipitated iron oxide can then be filtered off or allowed to settle, and the clear liquor, after having been made up to a definite specific gravity, used as required.

Calcium hypochlorite (bleaching powder) is also at times met with as an impurity in calcium chloride. It may be detected by making the solution distinctly acid with hydrochloric acid, and then adding potassium iodide and starch solution. Any blue colouration indicates the presence of hypochlorites. The reaction is quantitative.

If a known weight of the sample is treated in this way, and then titrated with sodium thiosulphate until the blue colour is just destroyed, a proportionate amount of thiosulphate can be added to the calcium chloride solution before it is added to the size.

It must be borne in mind that calcium chloride cannot be used in a mixing that contains soluble sulphates. A reaction takes place resulting in the formation of insoluble crystalline calcium sulphate. If the sulphate was introduced as sodium sulphate, the products of the reaction will be calcium sulphate and sodium chloride—a soluble weighting material

and a deliquescent replaced by another soluble weighting material (sodium chloride) and a harsh non-deliquescent insoluble material.

Glycerine.

When a fat is boiled with caustic soda, we obtain soap, and an impure solution of glycerine. Formerly glycerine was regarded as a useless by-product, but since the advent of nitroglycerine explosives, glycerine has become a most important source of profit to the soap boiler, and its price has in consequence risen until it is almost too expensive to use as a softener. In certain classes of pure sizing, however, it is still employed.

Pure glycerine is a colourless and odourless thick liquid, with a specific gravity of 1·26. It dissolves freely in water, and carries with it none of the liability to tendering that follows on the use of magnesium or calcium chlorides.

As in the case of other deliquescents, it should not be used without an antiseptic. Owing to its high price glycerine is frequently adulterated: in fact I have met with samples of so-called glycerine that contained no trace whatever of this substance.

When glycerine is heated in a basin it boils away, giving off inflammable vapors of glycerine mixed with acrolein, the presence of which causes these vapours to be very irritating to the eyes and throat. It is completely volatile, and should leave neither a mass of carbon nor a fusible mineral residue. Should the residue char, the presence of glucose may be inferred. A white fusible residue, almost completely soluble in water, indicates the probable presence of chlorides, usually of calcium or magnesium.

These are confirmed by adding either to the original substance, or to a solution of the residue after ignition,

some silver nitrate. A white curdy precipitate proves that chlorides are present. Glucose is detected by its reducing action on Fehling's solution (see p. 77).

Glucose.

This substance comes into the market either as a colourless, sweet syrup, closely resembling glycerine in appearance, or as soft white lumps.

It is not nearly so hygroscopic as the softeners already alluded to. It is more used for finishing than for sizing. It is an excellent nutritive medium for fungi: so that cloth containing glucose becomes mildewed with great readiness, unless a sufficient quantity of antiseptic is added along with it. Glucose syrup is often sold under the name of "Glycerine Substitute."

CHAPTER IV

ANTISEPTICS

The more commonly used substances added to size to prevent the formation of mildew in the cloth are—

Zinc chloride.	Phenol (Carbolic acid).
Salicylic acid.	Cresol.
Thymol.	Formaldehyde.

Zinc Chloride ($ZnCl_2$).

Zinc Chloride is generally prepared by the action of hydrochloric acid on excess of metallic zinc, and evaporation of the resulting solution to a density of 1·46 to 1·52.

Any iron present in the zinc is liable to go into solution as ferrous chloride. In order to remove this, it has to be oxidised to ferric chloride, and then precipitated as ferric oxide by the addition of zinc or calcium carbonate.

The best method of oxidation, but a slow one, is to expose the solution freely to the air. The oxidation is more frequently effected by adding bleaching powder. If bleaching powder or chalk are used in the purification, calcium chloride is of necessity introduced into the finished article, consequently the strength of a zinc chloride solution cannot be safely determined by the hydrometer, until the absence of all adulterants has been clearly proved.

Adulteration of zinc chloride is extremely objectionable. The adulterated article is not only reduced in

money value, but may be the cause of serious losses from mildew, as the sizer will be led into the addition of insufficient chloride to his size to render the cloth antiseptic. The adulterants to be looked for in zinc chloride are—

Sodium chloride.	Magnesium sulphate.
Calcium chloride.	Sodium sulphate.

Impurities:

Iron chloride.	Ammonium chloride.
Lead chloride.	Free hydrochloric acid.

Recognition of Adulterants.

Sodium Chloride.—This is detected and estimated as already described under "Magnesium Chloride," p. 61. One volume of zinc chloride is mixed with two volumes of strong hydrochloric acid, when any salt present is precipitated. The precipitate can be washed with hydrochloric acid till free from zinc, dried and weighed. Sodium chloride is never present in zinc chloride unless it has been added with intent to defraud.

Calcium Chloride, Magnesium Chloride.—Neither of these substances will be found naturally in zinc chloride except in small quantities when they have been used to remove iron salts or small traces of free acid.

Their detection and estimation is carried out as follows:—

About a gramme of the sample is weighed out into a flask and boiled with a few drops of nitric acid. Ammonium chloride and excess of ammonia are then added, followed by sufficient ammonium sulphide to precipitate all the zinc. Zinc sulphide may be very difficult to filter. At first it passes through the filter paper; then it stops up the pores of the paper, and

filtration becomes very slow. It may, however, be brought into a suitable condition for filtration by the cautious addition of mercuric chloride; the black mercuric sulphide carrying down with it the lighter and finer zinc sulphide.

The precipitate is filtered and washed till free from chlorides, the washings being added to the bulk of the filtrate. The filtrate is now brought to the boil, and crystals of ammonium oxalate dropped in until no further precipitate forms. It is well to remove the flask from the flame before adding the first crystal of ammonium oxalate, as a violent ebullition frequently results, which may cause the contents of the flask to be lost. A solution of ammonium oxalate should not be added, as the precipitate formed in this case is very fine and cannot be filtered until it has been allowed to stand in a warm place for several hours. The precipitate formed from the crystalline oxalate is coarse, and filters readily after about five minutes boiling. The calcium oxalate is filtered off, washed and ignited, finally over a blow pipe, in a crucible of known weight. The calcium oxalate is converted into calcium oxide, and is weighed as such. The filtrate and washings from the calcium oxalate are made strongly alkaline with ammonia, and excess of sodium hydrogen phosphate is added. Magnesium is precipitated as the double phosphate $MgNH_4PO_4$. This is allowed to stand for twelve hours, filtered, and washed with one volume of ammonia, sp. gr. ·880 to two volumes of water, until free from the sodium salt. The precipitate is then dried and ignited, at first cautiously, and then finally over the blow pipe, and weighed as magnesium pyrophosphate $Mg_2P_2O_7$.

$$112{\cdot}4 \text{ parts } Mg_2P_2O_7 = 95{\cdot}4 \text{ parts } MgCl_2.$$

Magnesium Sulphate, Sodium Sulphate.—The sample is acidified with hydrochloric acid, and barium chloride

added. A white precipitate of barium sulphate indicates the presence of a soluble sulphate. Both are equally objectionable, as they are not antiseptic or deliquescent. If it is desired to estimate the quantity of sulphates present, certain precautions must be taken, or the barium sulphate will not be filterable.

One or two grammes of the zinc chloride are weighed into a flask, acidulated with hydrochloric acid, and diluted with about 100 c.c. of distilled water.

About 2 grammes of barium chloride are dissolved in 50 c.c. of water in another flask and also made acid with a little hydrochloric. Both solutions are then brought to the boil, the barium chloride solution is poured into the boiling zinc chloride solution, and this is kept boiling for five minutes. Precipitated in this way the barium sulphate is quite coarse, and can be filtered and washed without any trouble. The precipitate is dried, introduced into a weighed crucible and ignited.

When the filter paper is all burnt, the crucible is allowed to cool and the contents moistened with one drop of strong nitric acid and two drops of sulphuric acid. The acids are carefully evaporated, and the crucible heated over a blow pipe until the weight is constant.

$$233{\cdot}5 \text{ parts } BaSO_4 = 120{\cdot}5 \text{ parts } MgSO_4.$$
$$\text{or } 142{\cdot}2 \text{ parts } Na_2SO_4.$$

Lead Chloride.—Lead will only be present in zinc chloride in small quantities, but it is a highly objectionable impurity nevertheless. It is not easily washed out of the cloth, and remains as lead oxide after the alkaline scouring. When the cloth comes to be "chemicked," it is converted into lead peroxide: and when this comes to be boiled a second time with alkali,

it oxidises the cloth, and gives rise to very serious tendering.

Lead is detected by adding to the zinc chloride solution hydrochloric acid, followed by hydrogen sulphide.

As little as one part in 100,000 may easily be detected by the brown colouration produced. In larger quantities the lead will be precipitated as black or brown lead sulphide.

Iron Chloride.—Ammonia is added until the precipitate of zinc hydrate first formed is redissolved, when the iron will remain in suspension as brown flocculent ferric hydroxide. This may be filtered off, washed free from zinc, and treated on the filter with acidulated potassium ferrocyanide. Any iron present will then be converted into Prussian blue.

The Prussian blue test cannot be applied to the original liquor, as zinc ferrocyanide will be formed, and will mask the colour of Prussian blue.

Free Acid.—Zinc chloride is neutral to methyl orange. Hence, if the solution reddens methyl orange, it should be corrected before use by the addition of a little zinc oxide or ammonia.

The Use of Zinc Chloride in Sizing.—Zinc chloride is the most frequently used of all antiseptics. It is colourless, odourless and cheap. Like magnesium chloride, however, it decomposes on heating into free acid, and will thus cause tendering if cloth containing it is subjected to the singeing process before having been washed. It has been found by experience that when flour is an ingredient of the size, one part by weight of actual zinc chloride must be added for every eight parts of dry flour in order to render the cloth immune from mildew. Starches do not present such a favourable medium for the growth of spores, and one part of zinc chloride will sterilise twelve parts of starch. Highly nitrogenous ingredients

such as glue or casein will require more antiseptic than flour.

Zinc chloride is very soluble in water; hence, if the cloth should happen to get wet, the antiseptic will be washed out before the other ingredients of the size, and goods that would have been quite safe under ordinary conditions will very rapidly be ruined if they have been accidentally rained upon before shipment, or if sea water has obtained access to the bales on the voyage.

The author has seen cloth, properly sized, and shipped in airtight, tin-lined cases that had become quite mouldy. This disaster was traced to the fact that the cloth was packed rather damp. On arrival at the Eastern port the cases stood for some days on the quay exposed to bright sunshine. This had apparently strongly heated one side of the cases, and had caused the excess of moisture to distil over and condense on the cooler side. The condensed water had dissolved the zinc chloride and carried it away to the lower portions of the case which were quite wet, but free from mildew. This had developed mainly along the one edge of the central pieces of cloth, where most zinc had been washed out.

The fact that zinc chloride is cheap, and very deliquescent, renders its position as the favourite antiseptic almost unassailable. To cloth containing 20 per cent. of flour there must have been added nearly 3 per cent. of zinc chloride, and this will attract at least 3 per cent. of moisture. Thus we have not only the antiseptic property to consider, for which the zinc was originally added, but the 6 per cent. of added weight, and the softening effect to which no numerical value can be assigned.

Salicylic Acid ($C_6H_4.OH.COOH$).

Salicylic Acid is a white crystalline powder, very insoluble in cold water, but freely soluble on boiling.

It is odourless, and unaffected by any of the ordinary weighting or softening ingredients of the size.

It combines with alkalies by reason of its acid character, forming neutral salicylates, whose antiseptic power is only one-third that of the acid. Six ounces of salicylic acid will completely sterilise 100 lbs. of starch. For 100 lbs. of flour 8 ozs. are required. Salicylic acid may be recognised by the intense violet colour produced in its solution on addition of a small quantity of ferric chloride. On ignition it should be completely volatile.

Thymol ($C_6H_3.CH_3.C_3H_7.OH$).

Thymol forms colourless crystalline plates, very insoluble in cold water; a saturated solution containing only 3 per cent. It has a feeble aromatic smell, and a burning taste. It is an extremely powerful antiseptic. One ounce is sufficient to sterilise 100 lbs. of starch or about 80 lbs. of flour.

Phenol (Carbolic Acid) ($C_6H_5.OH$).

Phenol is obtained from coal tar. The pure substance forms colourless deliquescent crystals, which take up water to form a thick heavy oil. This oil slowly dissolves in water, a saturated solution containing 6 per cent. of actual phenol. In the presence of a small quantity of alkali or soap, phenol is much more soluble. It is also freely soluble in glycerine. A 50 per cent. solution in glycerine is miscible to any extent with water. Pure phenol has a characteristic and by no means disagreeable smell, but the cheaper, impure varieties possess a harsh smoky odour, which forms an insuperable bar to their extended use as antiseptics in sizing. Ten ounces of crystallised carbolic acid are sufficient to protect 100 lbs. of starch or 80 lbs. of flour. The crude varieties can be valued

chemically, but the results are not very reliable. The most satisfactory method is to prepare a quantity of 10 per cent. flour paste, to divide this into equal portions, and to add to each portion a known percentage of the samples to be compared. The pastes are then spread out into glass plates, or poured into shallow dishes, and kept under observation in a warm damp place until mildew appears. From the length of time before its appearance, and the vigour of its subsequent development, very reliable inferences can be drawn as to the relative value of the samples being tested.

Cresol ($C_6H_4.CH_3.OH$).

In all its essential properties *cresol* closely resembles phenol. Its antiseptic power is the same as that of phenol, but the smell is, if anything, somewhat more disagreeable.

Cresol and crude carbolic acid are both frequently adulterated with tar oils; substances of no antiseptic properties whatever. These may be roughly estimated as follows:—

A known volume of the sample is placed in a stoppered, graduated cylinder. Four times its volume of 10 per cent. caustic soda solution is added, and the mixture well shaken. The antiseptic will dissolve in the caustic soda, whilst the inactive oils will form a layer on the surface of the aqueous liquor. Should the two layers not separate readily, a known volume of benzene may be added, and the shaking repeated. The volume of the upper, oily layer is then read off (and the volume of benzene which has been added, deducted). From the difference the percentage by volume of oils can be calculated.

Formic Aldehyde (H.CHO).

This substance is sold as a 40 per cent. aqueous solution under the name of *Formalin*. It is prepared

by the limited oxidation of methyl alcohol, the gaseous product of the reaction being condensed in water. It is an excellent antiseptic, but since it is volatile, it is liable to be evaporated out of the warps during drying. Formalin, when added to solutions of gelatine or casein, causes instant coagulation; and after drying, the coagulated mass becomes quite insoluble in water or dilute alkalies.

Estimation.—Formic aldehyde combines with ammonia to form an insoluble compound, hexamethylene tetramine.

$$6H.CHO + 4NH_3 = (CH_2)_6H_4 + 6H_2O.$$

A known weight of formalin is mixed with excess of ammonia, and the ammonia left uncombined is titrated back with hydrochloric acid, using methyl orange as indicator.

1 c.c. Normal HCl = ·017 grammes NH_3
= ·045 grammes H.CHO.

CHAPTER V

ANALYSIS OF SIZED WARPS AND CLOTH

Before the quantitative analysis of a sample of sized cotton can be undertaken it is necessary to discover the nature of the ingredients that have to be estimated.

The sample is shaken with cold water and the solution filtered.

The filtrate may contain—

Dextrin.
Glucose.
Glycerine.
Sulphates and chlorides of Zinc, Calcium, Magnesium and Sodium.
Phenol, and other organic antiseptics.

The sample is boiled with water and the solution filtered. The filtrate may contain—

Starch.
Gelatine or Glue.
Casein.
Gums.
Soap.

Another portion of the sample is burnt. The ash may contain—

China clay.
Barium sulphate.
The mineral salts already enumerated.

Cold Water Extract.—Add a drop of iodine solution. A blue, purple or brown colouration indicates dextrin. The more the colouration tends towards brown, the more highly converted was the dextrin employed.

To another portion of the extract add ammonium chloride, ammonia and ammonium sulphide. A white precipitate indicates zinc. Filter if necessary, add ammonium carbonate and boil. A white precipitate indicates calcium. The filtrate is divided into two portions. To one portion add sodium phosphate. A white precipitate forming slowly indicates magnesium.

The other half of the filtrate is evaporated to dryness and ignited. If there was no magnesium found, any residue will consist of sodium salts. If magnesium was present, a portion of the residue is taken up on a platinum wire and held in a Bunsen flame. An intense yellow colouration of the flame indicates sodium.

Another portion of the cold water extract is examined for chlorides by the addition of a little nitric acid and silver nitrate.

Sulphates are detected in another portion by the white precipitate of barium sulphate formed on the addition of hydrochloric acid and barium chloride.

The remainder of the cold water extract is evaporated almost to dryness on the water bath. The organic antiseptics will be recognisable in the residue by their smell.

Glucose is detected by boiling a few drops of the residue with weak Fehling's solution. Glucose causes a yellow or red precipitate of cuprous oxide to be formed. If the quantity of glucose present is only very small, it may merely produce a green or yellow opalescence in the solution.

Glycerine is detected by adding a few grammes of potassium hydrogen sulphate to the residue and heating gently. If any glycerine is present it will be decomposed into acrolein which is recognised by its intensely irritating effect on the eyes and nose. The smell suggests burning fat, or a candle that has just been blown out.

Hot Water Extract.—Cool and add a drop of iodine solution. *Starch* gives an intense blue colour. The remainder of the extract is evaporated nearly to dryness on the water bath.

Glue and Casein will emit their characteristic odours, and can be recognised by the addition of a small quantity of tannic acid to a portion of the residue. Both glue and casein yield curdy precipitates.

Another portion of the residue is acidulated with a drop of dilute sulphuric acid. A turbidity, which disappears on warming, giving place to oily drops, and the characteristic rancid smell of fatty acids, indicates the presence of soap.

The gums, such as tragacanth, tragasol and Irish moss will also be present in the residue, but they present no definite chemical properties by which they can be recognised. Their presence can only be inferred from the appearance of the residue.

Residue after Incineration.—The residue, which must be ignited until quite white, is boiled with water, filtered and well washed. The filtrate will contain all the soluble mineral matters. The insoluble portions will contain all the china clay and barium sulphate, together with some calcium and magnesium compounds, which have become insoluble during the ignition.

Wash the insoluble portion out of the filter and boil for at least 15 minutes in a 5 per cent. solution of sodium carbonate, replacing the water as it evaporates. Filter. To the filtrate add hydrochloric acid in excess, and then barium chloride. Any white precipitate of barium sulphate indicates calcium or barium sulphates. The solution may become gelatinous after the addition of the acid. This is due to silicic acid, extracted from the china clay by the sodium carbonate.

The insoluble residue, after boiling with sodium carbonate, will contain aluminium hydroxide from the

clay, whilst the calcium, barium and magnesium compounds will have been converted into carbonates. Wash well, boil with dilute hydrochloric acid and filter.

To the filtrate add ammonium chloride and ammonia. The presence of *china clay* in the size will be indicated by the formation of a white flocculent precipitate of aluminium hydroxide.

Filter, add ammonium carbonate and boil. *Calcium and barium* are precipitated as carbonates.

Filter and wash the precipitate. The filtrate is examined for *magnesium* as before.

The carbonate precipitate is treated with boiling dilute acetic acid. To the solution is added dilute sulphuric acid. A white precipitate indicates *barium*. Filter off and add excess of ammonia and ammonium oxalate. Calcium is precipitated as calcium oxalate.

Quantitative Analysis.

A portion of the sample is weighed, and heated in a steam oven until dry. As cotton rapidly absorbs moisture from the air, all weighings should be carried out with the sample enclosed in a stoppered weighing bottle. The loss in weight gives the total moisture. The same portion is then boiled for 1 hour in a large volume of 1 per cent. caustic soda solution, well washed, boiled for 1 hour in ·5 per cent. hydrochloric acid solution, very well washed, and dried. The loss in weight gives the *Total Size*. Finally the sample is allowed to absorb moisture from the air, after which it is again weighed. The increase in weight gives the *natural moisture* in the cotton.

A second piece of the sample, weighing about 10 grammes, is extracted for 1 hour in the apparatus shown in Fig. 6.

C is a dry weighed flask, standing on the water bath D. It should hold from 150 to 250 c.c. C is connected

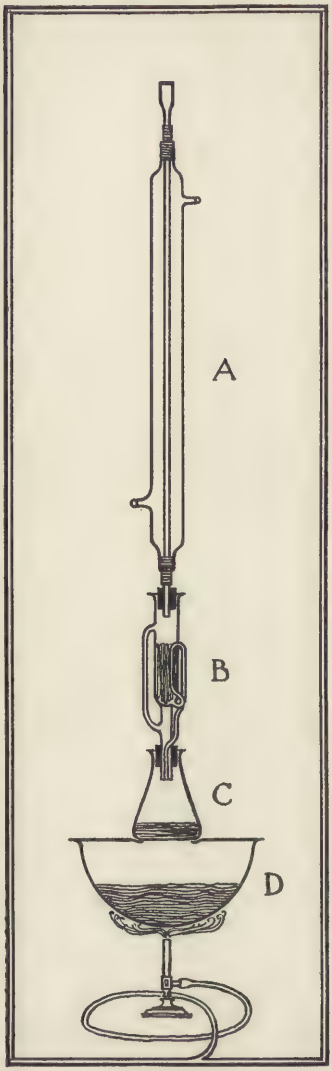


FIG. 6.

airtight by means of a cork to the Soxhlet extractor B, inside which is placed the weighed portion of the sample. The condenser A is fitted to the top of the Soxhlet. About 50 c.c. of light petrol, purified as described on p. 55, are placed in the flask C, and the water bath heated to such a temperature that the petrol drops rapidly from the lower end of A. At the end of the hour the light under the water bath is turned out, and the flask C disconnected. Any petrol remaining in B is poured back into the stock bottle, and the cloth preserved for future use. The flask C is now connected to another condenser, as shown in Fig. 5, p. 56, by means of the cork and bent tube E. The petrol distils over, and is collected in the flask F. It may be used over and over again.

It should be remembered that petrol gives off inflammable vapours, even at ordinary temperatures. The vapours

are very heavy, and flow like water along the surface of a bench, so that it is quite possible for a flask containing petrol to take fire from a burner 2 yards away on the bench. It should be made a rule that before any flask containing petrol is either connected or disconnected from the extractor or condenser all lights on the working bench must be turned out. A flask is liable to slip from the fingers occasionally and drop into the hot water bath. If there are any flames near a conflagration is inevitable. Nothing can be done until the flames begin to moderate, except to turn off the gas supply at the main.

As the supply of petrol becomes exhausted, the burning places should be covered over with wet dusters or towels in order to prevent unnecessary destruction of woodwork and apparatus. It perhaps goes without saying that the stock bottle of petrol should be stored as far away as possible from the place where the extractor is used.

When as much petrol as possible has distilled over, the lights are put out again, C is disconnected, and a current of air blown into its mouth to dissipate the remainder of the petrol. When this has gone, the flask is kept on the boiling water bath for a short time, blown once more, cooled, and weighed. The increase in weight gives the percentage of fat in the sample.

There is usually not sufficient fat to allow of a chemical analysis being made for its recognition. Generally it can be recognised by the smell and appearance. Should an analysis be essential, sufficient of the sample must be extracted to yield in all 3 or 4 grammes of fat.

The fat-free sample is now burnt in a weighed platinum crucible. The weight of ash found is not, however, the weight of the mineral matter in the original sample, since various substances lose more

water on ignition than they do when heated in the water oven. If china clay is present, 11 per cent. should be added to its weight, whilst the percentage of calcium sulphate found has to be increased by 26 per cent. If other mineral matters besides china clay have been found, the ash is warmed with strong hydrochloric acid and a few drops of dilute sulphuric acid. It is then taken up with water and filtered whilst hot. The filtrate is boiled with a little nitric acid, and ammonium chloride and excess of ammonia added.

This will precipitate alumina derived from the china clay. To the filtrate is then added ammonium sulphide to precipitate the zinc as zinc sulphide. The precipitate is filtered through a filter paper, the weight of whose ash is known, and well washed. The filter paper is then carefully ignited in a weighed crucible. The increase in weight, minus the weight of the filter paper ash, is zinc oxide.

The calcium in the filtrate from the zinc sulphide is next precipitated as follows. The liquor is brought to the boil, and small crystals of ammonium oxalate are thrown into the flask as long as any precipitate of calcium oxalate forms. The calcium oxalate produced in this way is coarse and easy to filter. If the ammonium oxalate is added in solution, the precipitate is very fine, and has to be allowed to stand for 12 hours before it can be filtered.

The calcium oxalate is filtered through a filter paper with known weight of ash, ignited in a crucible, at first carefully, finally over a blow-pipe, and weighed as calcium oxide. To the filtrate from the calcium oxalate is added strong ammonia and sodium phosphate. The magnesium is precipitated as $MgNH_4PO_4$. This substance is slightly soluble in water; it must be washed with weak ammonia solution, and weighed after ignition as $Mg_2P_2O_7$.

111·4 parts $Mg_2P_2O_7$ = 24·4 parts Mg.

If barium sulphate is known to be present, it must be determined in the insoluble residue left after heating the original ash with hydrochloric acid.

The filter paper and residue are introduced into a platinum crucible, dried and ignited, after which sodium carbonate is added, and the mixture heated over the blow-pipe until a clear melt, free from bubbles, is obtained. The crucible is now allowed to cool; it is then placed on its side in a beaker half full of water, and kept on the water bath until all of the cake has been dissolved out. The turbid solution is filtered and the residue thoroughly washed, the washings being thrown away, after which boiling dilute hydrochloric acid is poured on to the filter to dissolve the barium carbonate. After well washing the filter, the filtrate is brought to the boil, and boiling dilute sulphuric acid added in slight excess. The boiling is continued for 5 minutes, and then the barium sulphate is allowed to settle. It is finally washed with boiling water on to a filter paper, and ignited in a weighed platinum crucible. After all the paper is burnt, the residue is moistened with one drop of strong nitric acid, and one drop of strong sulphuric acid, ignited and weighed as barium sulphate.

The Soluble Sulphates and Chlorides have next to be determined. For this purpose about 30 grammes of the sample are placed in a large basin, and 100 c.c. of cold distilled water poured on to it. The sample is well worked in the water, and is then squeezed out into a 500 c.c. flask, any water remaining in the basin being also poured into the flask. The sample is washed six times in this way, until the flask is full up to the mark. When the contents of the flask have settled quite clear, portions of 50 c.c. or 100 c.c. are pipetted out for analysis.

The chlorides are determined by titration with N/10 silver nitrate, using potassium chromate as

indicator. A permanent red colour is produced in the milky liquor as soon as all the chlorides have been precipitated.

1 c.c. of N/10 solution $AgNO_3$ = ·00355 gr. Chlorine.

The sulphates are precipitated as barium sulphate. In order to obtain a filterable precipitate, the solution containing the sulphates is acidulated with hydrochloric acid and brought to the boil.

A 10 per cent solution of barium chloride is also acidulated with hydrochloric acid, brought to the boil and poured at once into the boiling sulphate solution.

The precipitate is ignited, treated with nitric and sulphuric acids, ignited again, and finally weighed as barium sulphate.

233 parts $BaSO_4$ = 96 parts SO_4.

It is not possible to determine the relative proportions of starch, dextrin, glue, etc., with any degree of accuracy, and of course it is quite impossible to determine, except from the feel of the sample, what starches have been used. The percentages of the various ingredients found are added up and deducted from 100, the difference being returned as starchy matters.

The weight of starch calculated in this way is not, however, the true weight of starch in the sample. The weight of the total size has been determined only after complete drying. Starch in its natural condition contains on the average 15 per cent. of moisture. Hence the weight of starch calculated by difference has to be increased by 15 per cent. to give the true weight of the starch present, and this moisture deducted from the total moisture found.

China clay is similarly determined by difference, when the ash contains more than one kind of mineral matter.

All the component parts of the sample have now been determined, but we still have to allocate the metals to their respective acid radicles.

The actual weights of clay and barium sulphate are known; also the weights of Cl, SO_4 and Mg.

Zinc and calcium have been weighed as oxides.

81 parts ZnO = 65 of Zn.
56 parts CaO = 40 of Ca.

A consideration of the following table of combining weights together with the known character of the sample, should enable us to form a fairly accurate idea of the actual compounds used in making the size.

Metals.	Acid radicles.
Zinc: 65.	SO_4: 96.
Calcium: 40.	Cl: 35·5.
Magnesium: 24.	
Sodium: 46.	

Sodium has not been estimated, but if its presence has been detected in the preliminary qualitative analysis, it will be found that there is an excess of acid radicle for which no metal has been found. This is then calculated into the corresponding quantity of sodium sulphate or chloride.

The complete analysis of a sample of warp or cloth is usually set out in the following manner.

Percentage of cotton . . . .
Percentage of natural moisture . .
Percentage of size . . . .

The size contains—

Mineral matters . . . .
Fats and oils . . . .
Starches . . . . .
Other organic substances . .
Moisture . . . . .

CHAPTER VI

THE PREPARATION OF NORMAL VOLUMETRIC SOLUTIONS

The volumetric solutions required for the analyses described in the foregoing chapters are the following:—

Normal hydrochloric acid.
Normal caustic soda.
Half normal alcoholic caustic potash.
One-tenth normal sodium thiosulphate.
One-tenth normal silver nitrate.

Various methods have been recommended for the preparation of standard solutions of acids and alkalies. The use of sodium carbonate is perhaps the most simple.

The first step is the preparation of an approximately normal solution of hydrochloric acid. This solution should contain 36·5 grammes of actual HCl per litre.

Pure strong hydrochloric acid is taken, and its density at 15° C. determined by means of a hydrometer or Westphal balance. From the density we can calculate the volume of acid which, when diluted to 1 or 2 litres, will give a solution of the desired strength. In order to ascertain the exact strength of the acid, it must be standardised against pure dry sodium carbonate.

From 6 to 10 grammes of pure anhydrous sodium carbonate are placed in a platinum crucible, which

should not be more than half full. The crucible is so arranged over a small burner that its bottom is heated to a just visible dull red. The sodium carbonate is gently stirred with a platinum wire for about 20 minutes, and then poured, whilst still hot, into a clean, dry test tube, which is at once corked, and placed in a dessicator until cool. When cool, the test tube is weighed, and about 1·5 to 2 grammes poured out into a clean dry flask. The cork is at once replaced, and the amount of carbonate poured out ascertained by re-weighing the test tube. Three or four lots of sodium carbonate are weighed out in this way. Each lot is then dissolved in about 50 c.c. of cold water, and sufficient alcoholic solution of methyl orange (1 gramme per litre) added to tint the solution a just visible yellow. The solution of hydrochloric acid is now brought by warming or cooling to 15° C., and its volume adjusted exactly to the mark on the neck of the graduated flask. A burette, graduated in $\frac{1}{10}$ c.c. is filled with the acid, and the volume determined that just causes the clear yellow colour of the sodium carbonate solution to become tinged with brown. A rosy pink indicates that too much acid has been added.

As it is not always quite easy to decide the exact point of the colour change, it is well to use the contents of the first flask after titration as a colour standard. The colour is brought back to yellow by the addition of a drop of alkali, and then this flask and the one being titrated are placed side by side on a sheet of white paper, when the least change in colour of the second flask can be seen at once.

A normal solution of sodium carbonate contains 53 grammes Na_2CO_3 per litre, and a given volume of this would be neutralised by the same volume of normal hydrochloric acid. Hence we can calculate the volume of normal acid that the weight of sodium carbonate taken for the titration should require.

This volume V will be given by the formula

$$V = 1{,}000 \times \frac{W}{53}$$

where W is the weight of sodium carbonate taken.

If V is exactly equal to the volume of hydrochloric acid used, the acid is normal. Usually, however, this volume will be either more or less than V, indicating that the acid is actually weaker or stronger than normal. It is not advisable to try to adjust the strength of the solution until it is correct. It is simpler and just as accurate to work out a "factor" If v be the volume of acid taken in the titration for W grammes of sodium carbonate, then the factor for the acid will be $\frac{V}{v}$. This factor is inscribed on the label of the bottle, and in every future analysis, the volume of acid used for a titration is multiplied by the factor.

Normal Caustic Soda.

A normal caustic soda solution should contain 40 grammes of sodium hydroxide per litre. Forty-two to 45 grammes of pure caustic are weighed out and dissolved to 1,000 c.c. in water that has been recently boiled and cooled, to expel carbon dioxide. The solution is allowed to stand until it has attained the same temperature as the standard HCl. This eliminates all corrections for differences in temperature. Twenty c.c. of the caustic solution are pipetted into a flask and titrated with methyl orange just in the same way as the sodium carbonate.

If v be the volume of hydrochloric acid required by 20 c.c. of the caustic solution, then this volume is equivalent to ($v \times HCl$ factor) c.c. of truly normal caustic. Hence the factor of the caustic soda solution will be

$$\frac{v \times HCl \text{ factor}}{20}.$$

Semi-normal Alcoholic Caustic Potash.

No factor is required for this solution, as it is never used without a "blank" titration by means of which the factor is ascertained every time it is used.

Thirty grammes of pure caustic potash are dissolved in 30 c.c. of water, and diluted to 1,000 c.c. with rectified spirit. A certain amount of potassium carbonate always separates out from this solution. Care should be taken when making an analysis that none of this is drawn up into the pipette.

Deci-normal Sodium Thiosulphate.

The sodium thiosulphate sold as pure is quite free from all impurities except moisture. About 30 grammes are finely ground and spread out in a thin layer between two white sheets of hard-faced filter paper. After 24 hours all excess of moisture should have disappeared. 24·83 grammes of the powder are weighed out and made up to 1,000 c.c. The solution does not maintain its strength for very long even in the dark. For accurate work its titre should not be relied on after it is three months old.

Deci-normal Silver Nitrate.

Exactly 17 grammes of pure silver nitrate are made up to 1,000 c.c. with distilled water. The solution should be kept in a bottle covered with black paper or Brunswick black.

CHAPTER VII

TABLES

DENSITY OF HYDROCHLORIC ACID SOLUTIONS (LUNGE AND MARCHLEWSKI).

Density at 15° C.	Degrees, Baumé.	Degrees, Twaddell.	Per cent. HCl.	Kilos. HCl in 1,000 c.c.	Density at 15° C.	Degrees, Baumé.	Degrees, Twaddell.	Per cent. HCl.	Kilos. HCl in 1,000 c.c.
1·000	0·0	0·0	0·16	0·0016	1·115	14·9	23	22·86	0·255
1·005	0·7	1	1·15	0·012	1·120	15·4	24	23·82	0·267
1·010	1·4	2	2·14	0·022	1·125	16·0	25	24·78	0·278
1·015	2·1	3	3·12	0·032	1·130	16·5	26	25·75	0·291
1·020	2·7	4	4·13	0·042	1·135	17·1	27	26·70	0·303
1·025	3·4	5	5·15	0·053	1·140	17·7	28	27·66	0·315
1·030	4·1	6	6·15	0·064	1·1425	18·0	—	28·14	0·322
1·035	4·7	7	7·15	0·074	1·145	18·3	29	28·61	0·328
1·040	5·4	8	8·16	0·085	1·150	18·8	30	29·57	0·340
1·045	6·0	9	9·16	0·096	1·152	19·0	—	29·95	0·345
1·050	6·7	10	10·17	0·107	1·155	19·4	31	30·55	0·353
1·055	7·4	11	11·18	0·118	1·160	19·8	32	31·52	0·366
1·060	8·0	12	12·19	0·129	1·163	20·0	—	32·10	0·373
1·065	8·7	13	13·19	0·141	1·165	20·3	33	32·49	0·379
1·070	9·4	14	14·17	0·152	1·170	20·9	34	33·46	0·392
1·075	10·0	15	15·16	0·163	1·171	21·0	—	33·65	0·394
1·080	10·6	16	16·15	0·174	1·175	21·4	35	34·42	0·404
1·085	11·2	17	17·13	0·186	1·180	22·0	36	35·39	0·418
1·090	11·9	18	18·11	0·197	1·185	22·5	37	36·31	0·430
1·095	12·4	19	19·06	0·209	1·190	23·0	38	37·23	0·443
1·100	13·0	20	20·01	0·220	1·195	23·5	39	38·16	0·456
1·105	13·6	21	20·97	0·232	1·200	24·0	40	39·11	0·469
1·110	14·2	22	21·92	0·243					

DENSITY OF SULPHURIC ACID SOLUTIONS (LANGE, ISLER, AND NAEF).

Density at 15° C.	Degrees, Beaumé.	Degrees, Twaddell.	Per cent. H_2SO_4.	Kilos. H_2SO_4 in 1,000 c.c.	Density at 15° C.	Degrees, Beaumé.	Degrees, Twaddell.	Per cent. H_2SO_4.	Kilos. H_2SO_4 in 1,000 c.c.
1·000	0	0	0·09	0·001	1·185	22·5	37	25·40	0·301
1·005	0·7	1	0·95	0·009	1·190	23·0	38	26·04	0·310
1·010	1·4	2	1·57	0·016	1·195	23·5	39	26·68	0·319
1·015	2·1	3	2·30	0·023	1·200	24·0	40	27·32	0·328
1·020	2·7	4	3·03	0·031	1·205	24·5	41	27·95	0·337
1·025	3·4	5	3·76	0·039	1·210	25·0	42	28·58	0·346
1·030	4·1	6	4·49	0·046	1·215	25·5	43	29·21	0·355
1·035	4·7	7	5·23	0·054	1·220	26·0	44	29·84	0·364
1·040	5·4	8	5·96	0·062	1·225	26·4	45	30·48	0·373
1·045	6·0	9	6·67	0·071	1·230	26·9	46	31·11	0·382
1·050	6·7	10	7·37	0·077	1·235	27·4	47	31·70	0·391
1·055	7·4	11	8·07	0·085	1·240	27·9	48	32·28	0·400
1·060	8·0	12	8·77	0·093	1·245	28·4	49	32·86	0·409
1·065	8·7	13	9·47	0·102	1·250	28·8	50	33·43	0·418
1·070	9·4	14	10·19	0·109	1·255	29·3	51	34·00	0·426
1·075	10·0	15	10·90	0·117	1·260	29·7	52	34·57	0·435
1·080	10·6	16	11·60	0·125	1·265	30·2	53	35·14	0·444
1·085	11·2	17	12·30	0·133	1·270	30·6	54	35·71	0·454
1·090	11·9	18	12·99	0·142	1·275	31·1	55	36·29	0·462
1·095	12·4	19	13·67	0·150	1·280	31·5	56	36·87	0·472
1·100	13·0	20	14·35	0·158	1·285	32·0	57	37·45	0·481
1·105	13·6	21	15·03	0·166	1·290	32·4	58	38·03	0·490
1·110	14·2	22	15·71	0·175	1·295	32·8	59	38·61	0·500
1·115	14·9	23	16·36	0·183	1·300	33·3	60	39·19	0·510
1·120	15·4	24	17·01	0·191	1·305	33·7	61	39·77	0·519
1·125	16·0	25	17·66	0·199	1·310	34·2	62	40·35	0·529
1·130	16·5	26	18·31	0·207	1·315	34·6	63	40·93	0·538
1·135	17·1	27	18·96	0·215	1·320	35·0	64	41·50	0·548
1·140	17·7	28	19·61	0·223	1·325	35·4	65	42·08	0·557
1·145	18·3	29	20·26	0·231	1·330	35·8	66	42·66	0·567
1·150	18·8	30	20·91	0·239	1·335	36·2	67	43·20	0·577
1·155	19·3	31	21·55	0·248	1·340	36.6	68	43·74	0·586
1·160	19·8	32	22·19	0·257	1·345	37·0	69	44·28	0·596
1·165	20·3	33	22·83	0·266	1·350	37·4	70	44·82	0·605
1·170	20·9	34	23·47	0·275	1·355	37·8	71	45·35	0·614
1·175	21·4	35	24·12	0·283	1·360	38·2	72	45·88	0·624
1·180	22·0	36	24·76	0·292	1·365	38·6	73	46·41	0·633

DENSITY OF SULPHURIC ACID SOLUTIONS—*continued.*

Density at 15° C.	Degrees, Beaumé.	Degrees, Twaddell.	Per cent. H_2SO_4.	Kilos. H_2SO_4 in 1,000 c.c.	Density at 15° C.	Degrees, Beaumé.	Degrees, Twaddell.	Per cent. H_2SO_4.	Kilos. H_2SO_4 in 1,000 c.c.
1·370	39·0	74	46·94	0·643	1·560	51·8	112	65·20	1·017
1·375	39·4	75	47·47	0·653	1·565	52·1	113	65·65	1·027
1·380	39·8	76	48·00	0·662	1·570	52·4	114	66·09	1·038
1·385	40·1	77	48·53	0·672	1·575	52·7	115	66·53	1·048
1·390	40·5	78	49·06	0·682	1·580	53·0	116	66·95	1·058
1·395	40·8	79	49·59	0·692	1·585	53·3	117	67·40	1·068
1·400	41·2	80	50·11	0·702	1·590	53·6	118	67·83	1·078
1·405	41·6	81	50·63	0·711	1·595	53·9	119	68·26	1·089
1·410	42·0	82	51·15	0·721	1·600	54·1	120	68·70	1·099
1·415	42·3	83	51·66	0·730	1·605	54·4	121	69·13	1·110
1·420	42·7	84	52·15	0·740	1·610	54·7	122	69·56	1·120
1·425	43·1	85	52·63	0·750	1·615	55·0	123	70·00	1·131
1·430	43·4	86	53·11	0·759	1·620	55·2	124	70·42	1·141
1·435	43·8	87	53·59	0·769	1·625	55·5	125	70·85	1·151
1·440	44·1	88	54·07	0·779	1·630	55·8	126	71·27	1·162
1·445	44·4	89	54·55	0·789	1·635	56·0	127	71·70	1·172
1·450	44·8	90	55·03	0·798	1·640	56·3	128	72·12	1·182
1·455	45·1	91	55·50	0·808	1·645	56·6	129	72·55	1·193
1·460	45·4	92	55·97	0·817	1·650	56·9	130	72·96	1·204
1·465	45·8	93	56·43	0·827	1·655	57·1	131	73·40	1·215
1·470	46·1	94	56·90	0·837	1·660	57·4	132	73·81	1·225
1·475	46·4	95	57·37	0·846	1·665	57·7	133	74·24	1·230
1·480	46·8	96	57·83	0·856	1·670	57·9	134	74·66	1·246
1·485	47·1	97	58·28	0·865	1·675	58·2	135	75·08	1·259
1·490	47·4	98	58·74	0·876	1·680	58·4	136	75·50	1·268
1·495	47·8	99	59·22	0·885	1·685	58·7	137	75·94	1·278
1·500	48·1	100	59·70	0·896	1·690	58·9	138	76·38	1·289
1·505	48·4	101	60·18	0·906	1·695	59·2	139	76·76	1·301
1·510	48·7	102	60·65	0·916	1·700	59·5	140	77·17	1·312
1·515	49·0	103	61·12	0·926	1·705	59·7	141	77·60	1·323
1·520	49·4	104	61·59	0·936	1·710	60·0	142	78·04	1·334
1·525	49·7	105	62·06	0·946	1·715	60·2	143	78·48	1·346
1·530	50·0	106	62·53	0·957	1·720	60·4	144	78·92	1·357
1·535	50·3	107	63·00	0·967	1·725	60·6	145	79·36	1·369
1·540	50·6	108	63·43	0·977	1·730	60·9	146	79·80	1·381
1·545	50·9	109	63·85	0·987	1·735	61·1	147	80·24	1·392
1·550	51·2	110	64·26	0·996	1·740	61·4	148	80·68	1·404
1·555	51·5	111	64·67	1·006	1·745	61·6	149	81·12	1·416

DENSITY OF SULPHURIC ACID SOLUTIONS—*continued.*

Density at 15° C.	Degrees, Beaumé.	Degrees, Twaddell.	Per cent. H_2SO_4.	Kilos. H_2SO_4 in 1,000 c.c.	Density at 15° C.	Degrees, Beaumé.	Degrees, Twaddell.	Per cent. H_2SO_4.	Kilos. H_2SO_4 in 1,000 c.c.
1·750	61·8	150	81·56	1·427	1·828	65·4	—	91·70	1·676
1·755	62·1	151	82·00	1·439	1·829	—	—	91·90	1·681
1·760	62·3	152	82·44	1·451	1·830	—	166	92·10	1·685
1·765	62·5	153	83·01	1·465	1·831	65·5	—	92·43	1·692
1·770	62·8	154	83·51	1·478	1·832	—	—	92·70	1·698
1·775	63·0	155	84·02	1·491	1·833	65·6	—	92·97	1·704
1·780	63·2	156	84·50	1·504	1·834	—	—	93·25	1·710
1·785	63·5	157	85·10	1·519	1·835	65·7	167	93·56	1·717
1·790	63·7	158	85·70	1·534	1·836	—	—	93·90	1·722
1·795	64·0	159	86·30	1·549	1·837	—	—	94·25	1·730
1·800	64·2	160	86·92	1·565	1·838	65·8	—	94·60	1·739
1·805	64·4	161	87·60	1·581	1·839	—	—	95·00	1·748
1·810	64·6	162	88·30	1·598	1·840	65·9	168	95·60	1·759
1·815	64·8	163	89·16	1·618	1·8405	—	—	95·95	1·765
1·820	65·0	164	90·05	1·639	1·8410	—	—	96·38	1·774
1·821	—	—	90·20	1·643	1·8415	—	—	97·35	1·792
1·822	65·1	—	90·40	1·647	1·8410	—	—	98·20	1·808
1·823	—	—	90·60	1·651	1·8405	—	—	98·52	1·814
1·824	65·2	—	90·80	1·656	1·8400	—	—	98·72	1·816
1·825	—	165	91·00	1·661	1·8395	—	—	98·77	1·817
1·826	65·3	—	91·25	1·666	1·8390	—	—	99·12	1·823
1·827	—	—	91·50	1·671	1·8385	—	—	99·31	1·826

The following works have been consulted in compiling these tables:—*Chemiker Kalendar*, *Lunge's Chemisch-technische Untersuchungsmethoden*, *The Bayer Company's Pocket Book*, *The Photographic Annual.*

DENSITY OF SODIUM HYDROXIDE SOLUTIONS.

Density at 15° C.	Degrees, Beaumé.	Degrees, Twaddell.	Per cent. NaOH.	Kilos. NaOH in 1,000 c.c.	Density at 15° C.	Degrees, Beaumé	Degrees, Twaddell.	Per cent. NaOH.	Kilos NaOH in 1,000 c.c.
1·007	1	1·4	0·61	6	1·220	26	44·0	19·58	239
1·014	2	2·8	1·20	12	1·231	27	46·2	20·59	253
1·022	3	4·4	2·00	21	1·241	28	48·2	21·42	266
1·029	4	5·8	2·71	28	1·252	29	50·4	22·64	283
1·036	5	7·2	3·35	35	1·263	30	52·6	23·67	299
1·045	6	9·0	4·00	42	1·274	31	54·8	24·81	316
1·052	7	10·4	4·64	49	1·285	32	57·0	25·80	332
1·060	8	12·0	5·29	56	1·297	33	59·4	26·83	348
1·067	9	13·4	5·87	63	1·308	34	61·6	27·80	364
1·075	10	15·0	6·55	70	1·320	35	64·0	28·83	381
1·083	11	16·6	7·31	79	1·332	36	66·4	29·93	399
1·091	12	18·2	8·00	87	1·345	37	69·0	31·22	420
1·100	13	20·0	8·68	95	1·357	38	71·4	32·47	441
1·108	14	21·6	9·42	104	1·370	39	74·0	33·69	462
1·116	15	23·2	10·06	112	1·383	40	76·6	34·96	483
1·125	16	25·0	10·97	123	1·397	41	79·4	36·25	506
1·134	17	26·8	11·84	134	1·410	42	82·0	37·47	528
1·142	18	28·4	12·64	144	1·424	43	84·8	38·80	553
1·152	19	30·4	13·55	156	1·438	44	87·6	39·99	575
1·162	20	32·4	14·37	167	1·453	45	90·6	41·41	602
1·171	21	34·2	15·13	177	1·468	46	93·6	42·83	629
1·180	22	36·0	15·91	188	1·483	47	96·6	44·38	658
1·190	23	38·0	16·77	200	1·498	48	99·6	46·15	691
1·200	24	40·0	17·67	212	1·514	49	102·8	47·60	721
1·210	25	42·0	18·58	225	1·530	50	106·0	49·02	750

DENSITY OF AMMONIA SOLUTIONS.

Density at 15° C.	Per cent. NH_3.	Grammes NH_3 in 1,000 c.c.	Density at 15° C.	Per cent. NH_3.	Grammes NH_3 in 1,000 c.c.
1·000	0·00	0·0	0·940	15·63	146·9
0·998	0·45	4·5	0·938	16·22	152·1
0·996	0·91	9·1	0·936	16·82	157·4
0·994	1·37	13·6	0·934	17·42	162·7
0·992	1·84	18·2	0·932	18·03	168·1
0·990	2·31	22·9	0·930	18·64	173·4
0·988	2·80	27·7	0·928	19·25	178·6
0·986	3·30	32·5	0·926	19·87	184·2
0·984	3·80	37·4	0·924	20·49	189·3
0·982	4·30	42·2	0·922	21·12	194·7
0·980	4·80	47·0	0·920	21·75	200·1
0·978	5·30	51·8	0·918	22·39	205·6
0·976	5·80	56·6	0·916	23·03	210·9
0·974	6·30	61·4	0·914	23·68	216·3
0·972	6·80	66·1	0·912	24·33	221·9
0·970	7·31	70·9	0·910	24·99	227·4
0·968	7·82	75·7	0·908	25·65	232·9
0·966	8·33	80·5	0·906	26·31	238·3
0·964	8·84	85·2	0·904	26·98	243·9
0·962	9·35	89·9	0·902	27·65	249·4
0·960	9·91	95·1	0·900	28·33	255·0
0·958	10·47	100·3	0·898	29·01	260·5
0·956	11·03	105·4	0·896	29·69	266·0
0·954	11·60	110·7	0·894	30·37	271·5
0·952	12·17	115·9	0·892	31·05	277·0
0·950	12·74	121·0	0·890	31·75	282·6
0·948	13·31	126·2	0·888	32·50	288·6
0·946	13·88	131·3	0·886	33·25	294·6
0·944	14·46	136·5	0·884	34·10	301·4
0·942	15·04	141·7	0·882	34·95	308·3

DENSITY OF ZINC CHLORIDE SOLUTIONS.

Density at 19·5 °C.	Per cent. $ZnCl_2$.
1·045	5
1·091	10
1·137	15
1·186	20
1·238	25
1·291	30
1·352	35
1·420	40
1·488	45
1·566	50
1·650	55
1·740	60

DENSITY OF ZINC SULPHATE SOLUTIONS.

Density at 15° C.	Per cent. $ZnSO_4$ 7 H_2O.
1·0288	5
1·0593	10
1·0905	15
1·1236	20
1·1574	25
1·1932	30
1·231	35
1·2709	40
1·310	45
1·2522	50
1·3986	55
1·4451	60

DENSITY OF CALCIUM CHLORIDE SOLUTIONS.

Density at 18·3° C.	Per cent. $CaCl_2$. 6 H_2O.	Per cent. $CaCl_2$.	Density at 18·3° C.	Per cent. $CaCl_2$. 6 H_2O.	Per cent. $CaCl_2$.
1·0039	1	0·507	1·1575	36	18·245
1·0079	2	1·014	1·1622	37	18·752
1·0119	3	1·521	1·1671	38	19·259
1·0159	4	2·028	1·1719	39	19·766
1·0200	5	2·535	1·1768	40	20·272
1·0241	6	3·041	1·1816	41	20·779
1·0282	7	3·548	1·1865	42	21·286
1·0323	8	4·055	1·1914	43	21·793
1·0365	9	4·562	1·1963	44	22·300
1·0407	10	5·068	1·2012	45	22·806
1·0449	11	5·575	1·2062	46	23·313
1·0491	12	6·082	1·2112	47	23·820
1·0534	13	6·587	1·2162	48	24·327
1·0577	14	7·096	1·2212	49	24·834
1·0619	15	7·601	1·2262	50	25·340
1·0663	16	8·107	1·2312	51	25·847
1·0706	17	8·611	1·2363	52	26·354
1·0750	18	9·121	1·2414	53	26·861
1·0794	19	9·625	1·2465	54	27·368
1·0838	20	10·136	1·2516	55	27·874
1·0882	21	10·643	1·2567	56	28·381
1·0927	22	11·150	1·2618	57	28·888
1·0972	23	11·657	1·2669	58	29·395
1·1017	24	12·164	1·2721	59	29·902
1·1062	25	12·670	1·2773	60	30·408
1·1107	26	13·177	1·2825	61	30·915
1·1153	27	13·684	1·2877	62	31·422
1·1199	28	14·191	1·2929	63	31·929
1·1246	29	14·698	1·2981	64	32·436
1·1292	30	15·204	1·3034	65	32·942
1·1339	31	15·711	1·3087	66	33·449
1·1386	32	16·218	1·3140	67	33·956
1·1433	33	16·725	1·3193	68	34·463
1·1480	34	17·232	1·3246	69	34·970
1·1527	35	17·738	1·3300	70	35·476

DENSITY OF MAGNESIUM CHLORIDE SOLUTIONS.

Density at 24° C.	Per cent. $MgCl_2$. 6 H_2O.	Per cent. $MgCl_2$.	Density at 24° C.	Per cent. $MgCl_2$. 6 H_2O.	Per cent. $MgCl_2$.
1·0069	2	0·936	1·1519	42	19·656
1·0138	4	1·872	1·1598	44	20·592
1·0207	6	2·808	1·1677	46	21·528
1·0276	8	3·744	1·1756	48	22·464
1·0345	10	4·680	1·1836	50	23·400
1·0415	12	5·616	1·1918	52	24·336
1·0485	14	6·552	1·2000	54	25·272
1·0556	16	7·488	1·2083	56	26·208
1·0627	18	8·424	1·2167	58	27·144
1·0698	20	9·360	1·2252	60	28·080
1·0770	22	10·296	1·2338	62	29·016
1·0842	24	11·232	1·2425	64	29·952
1·0915	26	12·168	1·2513	66	30·888
1·0988	28	13·104	1·2602	68	31·824
1·1062	30	14·040	1·2692	70	32·760
1·1137	32	14·976	1·2783	72	33·696
1·1212	34	15·912	1·2875	74	34·632
1·1288	36	16·848	1·2968	76	35·568
1·1364	38	17·784	1·3063	78	36·504
1·1441	40	18·720	1·3159	80	37·440

DENSITY OF MAGNESIUM SULPHATE SOLUTIONS.

Density at 15° C.	Per cent. $MgSO_4$. 7 H_2O.	Per cent. $MgSO_4$.	Density at 15° C.	Per cent. $MgSO_4$. 7 H_2O.	Per cent. $MgSO_4$.
1·02062	4·097	2	1·17420	32·780	16
1·04123	8·185	4	1·19816	36·877	18
1·06229	12·292	6	1·22212	40·975	20
1·08379	16·390	8	1·24718	45·072	22
1·10529	20·487	10	1·27225	49·170	24
1·12806	24·585	12	1·28802	51·726	25·25
1·15083	28·682	14			

DENSITY OF SODIUM CHLORIDE SOLUTIONS.

Density at 15° C.	Per cent. NaCl.	Density at 15° C.	Per cent. NaCl.	Density at 15° C.	Per cent. NaCl.
1·00725	1	1·07335	10	1·14315	19
1·01450	2	1·08097	11	1·15107	20
1·02174	3	1·08859	12	1·15931	21
1·02899	4	1·09622	13	1·16755	22
1·03624	5	1·10384	14	1·17580	23
1·04366	6	1·11146	15	1·18404	24
1·05108	7	1·11938	16	1·19228	25
1·05851	8	1·12730	17	1·20098	26
1·06593	9	1·13523	18	1·20433	26·395

DENSITY OF SODIUM SULPHATE SOLUTIONS.

Density at 19° C.	Per cent. Na_2SO_4. 10 H_2O.	Per cent. Na_2SO_4.	Density at 19° C.	Per cent. Na_2SO_4. 10 H_2O.	Per cent. Na_2SO_4.
1·0040	1	0·441	1·0642	16	7·056
1·0079	2	0·881	1·0683	17	7·497
1·0118	3	1·323	1·0725	18	7·938
1·0158	4	1·764	1·0766	19	8·379
1·0198	5	2·205	1·0807	20	8·820
1·0238	6	2·646	1·0849	21	9·261
1·0278	7	3·087	1·0890	22	9·702
1·0318	8	3·528	1·0931	23	10·143
1·0358	9	3·969	1·0973	24	10·584
1·0398	10	4·410	1·1015	25	11·025
1·0439	11	4·851	1·1057	26	11·466
1·0479	12	5·292	1·1100	27	11·907
1·0520	13	5·373	1·1142	28	12·348
1·0560	14	6·174	1·1184	29	12·789
1·0601	15	6·615	1·1226	30	13·230

DENSITY OF ACETIC ACID SOLUTIONS.

Density at 15° C.	Per cent. CH_3COOH.	Density at 15° C.	Per cent. CH_3COOH.	Density at 15° C.	Per cent. CH_3COOH.	Density at 15° C.	Per cent. CH_3COOH.
0·9992	0	1·0363	26	1·0631	52	1·0748	77
1·0007	1	1·0375	27	1·0638	53	1·0748	78
1·0022	2	1·0388	28	1·0646	54	1·0748	79
1·0037	3	1·0400	29	1·0653	55	1·0748	80
1·0052	4	1·0412	30	1·0660	56	1·0747	81
1·0067	5	1·0424	31	1·0666	57	1·0746	82
1·0083	6	1·0436	32	1·0673	58	1·0744	83
1·0098	7	1·0447	33	1·0679	59	1·0742	84
1·0113	8	1·0459	34	1·0685	60	1·0739	85
1·0127	9	1·0470	35	1·0691	61	1·0736	86
1·0142	10	1·0481	36	1·0697	62	1·0731	87
1·0157	11	1·0492	37	1·0702	63	1·0726	88
1·0171	12	1·0502	38	1·0707	64	1·0720	89
1·0185	13	1·0513	39	1·0712	65	1·0713	90
1·0200	14	1·0523	40	1·0717	66	1·0705	91
1·0214	15	1·0533	41	1·0721	67	1·0696	92
1·0228	16	1·0543	42	1·0725	68	1·0686	93
1·0242	17	1·0552	43	1·0729	69	1·0674	94
1·0256	18	1·0562	44	1·0733	70	1·0660	95
1·0270	19	1·0571	45	1·0737	71	1·0644	96
1·0284	20	1·0580	46	1·0740	72	1·0625	97
1·0298	21	1·0589	47	1·0742	73	1·0604	98
1·0311	22	1·0598	48	1·0744	74	1·0580	99
1·0324	23	1·0607	49	1·0746	75	1·0553	100
1·0337	24	1·0615	50	1·0747	76		
1·0350	25	1·0623	51				

DENSITY OF FORMALIN SOLUTIONS (LÜTTKE).

Per cent. HCHO.	Density at 18·5° C.	Per cent. HCHO.	Density at 18·5° C.	Per cent. HCHO.	Density at 18·5° C.	Per cent. HCHO.	Density at 18·5° C.
1	1·002	11	1·027	21	1·052	31	1·076
2	1·004	12	1·029	22	1·055	32	1·077
3	1·007	13	1·031	23	1·058	33	1·078
4	1·008	14	1·033	24	1·061	34	1·079
5	1·015	15	1·036	25	1·064	35	1·081
6	1·017	16	1·039	26	1·067	36	1·082
7	1·019	17	1·041	27	1·069	37	1·083
8	1·020	18	1·043	28	1·071	38	1·085
9	1·023	19	1·045	29	1·073	39	1·086
10	1·025	20	1·049	30	1·075	40	1·087

DENSITY OF GLYCERINE SOLUTIONS.

Per cent. Water.	Density at 15° C.	Per cent. Water.	Density at 15° C.
0	1·2640	11·5	1·2335
0·5	1·2625	12·0	1·2322
1·0	1·2612	12·5	1·2307
1·5	1·2600	13·0	1·2295
2·0	1·2585	13·5	1·2280
2·5	1·2575	14·0	1·2270
3·0	1·2560	14·5	1·2255
3·5	1·2545	15·0	1·2242
4·0	1·2532	15·5	1·2230
4·5	1·2520	16·0	1·2217
5·0	1·2505	16·5	1·2202
5·5	1·2490	17·0	1·2190
6·0	1·2480	17·5	1·2177
6·5	1·2465	18·0	1·2165
7·0	1·2455	18·5	1·2150
7·5	1·2440	19·0	1·2137
8·0	1·2427	19·5	1·2125
8·5	1·2412	20·0	1·2112
9·0	1·2400	20·5	1·2100
9·5	1·2390	21·0	1·2085
10·0	1·2375	25	1·187
10·5	1·2362	30	1·169
11·0	1·2350		

DENSITY OF GLYCERINE SOLUTIONS—*continued.*

Per cent. Water.	Density at 15° C.	Per cent. Water.	Density at 17·5° C.
35	1·155	60	1·105
40	1·144	70	1·075
45	1·130	80	1·051
50	1·117	90	1·024

TABLES FOR THE COMPARISON OF SPECIFIC GRAVITY, DEGREES BEAUMÉ AND DEGREES TWADDELL.

FOR LIQUIDS LIGHTER THAN WATER.

Specific Gravity.	Degrees Beaumé.	Specific Gravity.	Degrees Beaumé.
1·0000	10	0·8488	36
0·9932	11	0·8439	37
0·9865	12	0·8391	38
0·9799	13	0·8343	39
0·9733	14	0·8295	40
0·9669	15	0·8249	41
0·9605	16	0·8202	42
0·9542	17	0·8156	43
0·9480	18	0·8111	44
0·9420	19	0·8066	45
0·9359	20	0·8022	46
0·9299	21	0·7978	47
0·9241	22	0·7935	48
0·9183	23	0·7892	49
0·9125	24	0·7849	50
0·9068	25	0·7807	51
0·9012	26	0·7766	52
0·8957	27	0·7725	53
0·8902	28	0·7684	54
0·8848	29	0·7643	55
0·8795	30	0·7604	56
0·8742	31	0·7565	57
0·8690	32	0·7526	58
0·8639	33	0·7487	59
0·8588	34	0·7449	60
0·8538	35		

FOR LIQUIDS HEAVIER THAN WATER.

Specific Gravity.	Degrees Twaddell.	Degrees Beaumé.	Specific Gravity.	Degrees Twaddell.	Degrees Beaumé.
1·000	0	0·0	1·195	39	23·5
1·005	1	0·7	1·200	40	24·0
1·010	2	1·4	1·205	41	24·5
1·015	3	2·1	1·210	42	25·0
1·020	4	2·7	1·215	43	25·5
1·025	5	3·4	1·220	44	26·0
1·030	6	4·1	1·225	45	26·4
1·035	7	4·7	1·230	46	26·9
1·040	8	5·4	1·235	47	27·4
1·045	9	6·0	1·240	48	27·9
1·050	10	6·7	1·245	49	28·4
1·055	11	7·4	1·250	50	28·8
1·060	12	8·0	1·255	51	29·3
1·065	13	8·7	1·260	52	29·7
1·070	14	9·4	1·265	53	30·2
1·075	15	10·0	1·270	54	30·6
1·080	16	10·6	1·275	55	31·1
1·085	17	11·2	1·280	56	31·5
1·090	18	11·9	1·285	57	32·0
1·095	19	12·4	1·290	58	32·4
1·100	20	13·0	1·295	59	32·8
1·105	21	13·6	1·300	60	33·3
1·110	22	14·2	1·305	61	33·7
1·115	23	14·9	1·310	62	34·2
1·120	24	15·4	1·315	63	34·6
1·125	25	16·0	1·320	64	35·0
1·130	26	16·5	1·325	65	35·4
1·135	27	17·1	1·330	66	35·8
1·140	28	17·7	1·335	67	36·2
1·145	29	18.3	1·340	68	36·6
1·150	30	18·8	1·345	69	37·0
1·155	31	19·3	1·350	70	37·4
1·160	32	19·8	1·355	71	37·8
1·165	33	20·3	1·360	72	38·2
1·170	34	20·9	1·365	73	38·6
1·175	35	21.4	1·370	74	39·0
1·180	36	22·0	1·375	75	39·4
1·185	37	22·5	1·380	76	39·8
1·190	38	23·0	1·385	77	40·1

FOR LIQUIDS HEAVIER THAN WATER—*continued.*

Specific Gravity.	Degrees Twaddell.	Degrees Beaumé.	Specific Gravity.	Degrees Twaddell.	Degrees Beaumé.
1·390	78	40·5	1·585	117	53·3
1·395	79	40·8	1·590	118	53·6
1·400	80	41·2	1·595	119	53·9
1·405	81	41·6	1·600	120	54·1
1·410	82	42·0	1·605	121	54·4
1·415	83	42·3	1·610	122	54·7
1·420	84	42·7	1·615	123	55·0
1·425	85	43·1	1·620	124	55·2
1·430	86	43·4	1·625	125	55·5
1·435	87	43·8	1·630	126	55·8
1·440	88	44·1	1·635	127	56·0
1·445	89	44·4	1·640	128	56·3
1·450	90	44·8	1·645	129	56·6
1·455	91	45·1	1·650	130	56·9
1·460	92	45·4	1·655	131	57·1
1·465	93	45·8	1·660	132	57·4
1·470	94	46·1	1·665	133	57·7
1·475	95	46·4	1·670	134	57·9
1·480	96	46·8	1·675	135	58·2
1·485	97	47·1	1·680	136	58·4
1·490	98	47·4	1·685	137	58·7
1·495	99	47·8	1·690	138	58·9
1·500	100	48·1	1·695	139	59·2
1·505	101	48·4	1·700	140	59·5
1·510	102	48·7	1·705	141	59·7
1·515	103	49·0	1·710	142	60·0
1·520	104	49·4	1·715	143	60·2
1·525	105	49·7	1·720	144	60·4
1·530	106	50·0	1·725	145	60·6
1·535	107	50·3	1·730	146	60·9
1·540	108	50·6	1·735	147	61·1
1·545	109	50·9	1·740	148	61·4
1·550	110	51·2	1·745	149	61·6
1·555	111	51·5	1·750	150	61·8
1·560	112	51·8	1·755	151	62·1
1·565	113	52·1	1·760	152	62·3
1·570	114	52·4	1·765	153	62·5
1·575	115	52·7	1·770	154	62·8
1·580	116	53·0	1·775	155	63·0

FOR LIQUIDS HEAVIER THAN WATER—*continued.*

Specific Gravity.	Degrees Twaddell.	Degrees Beaumé.	Specific Gravity.	Degrees Twaddell.	Degrees Beaumé.
1·780	156	63·2	1·825	165	65·2
1·785	157	63·5	1·830	166	65·5
1·790	158	63·7	1·835	167	65·7
1·795	159	64·0	1·840	168	65·9
1·800	160	64·2	1·845	169	66·1
1·805	161	64·4	1·850	170	66·3
1·810	162	64·6	1·855	171	66·5
1·815	163	64·8	1·860	172	66·7
1·820	164	65·0	1·865	173	67·0

COMPARISON OF THERMOMETRIC SCALES.

To convert C° to R°, multiply t° C by $\frac{4}{5}$.
,, ,, C° ,, F°, ,, t° C ,, $\frac{9}{5}$ and add 32.
,, ,, R° ,, F°, ,, t° R ,, $\frac{9}{4}$,, ,, 32.
,, ,, R° ,, C°, ,, t° R ,, $\frac{5}{4}$.
,, ,, F° ,, C°, subtract 32 and multiply by $\frac{5}{9}$.
,, ,, F° ,, R°, ,, 32 ,, ,, ,, $\frac{4}{9}$.

TABLES OF COMPARISON OF THERMOMETRIC SCALES.

Centi-grade.	Fahrenheit.	Réaumur.	Centi-grade.	Fahrenheit.	Réaumur.
100	212	80	61	141·8	48·8
99	210·2	79·2	60	140	48
98	208·4	78·4	59	138·2	47·2
97	206·6	77·6	58	136·4	46·4
96	204·8	76·8	57	134·6	45·6
95	203	76	56	132·8	44·8
94	201·2	75·2	55	131	44
93	199·4	74·4	54	129·2	43·2
92	197·6	73·6	53	127·4	42·4
91	195·8	72·8	52	125·6	41·6
90	194	72	51	123·8	40·8
89	192·2	71·2	50	122	40
88	190·4	70·4	49	120·2	39·2
87	188·6	69·6	48	118·4	38·4
86	186·8	68·8	47	116·6	37·6
85	185	68	46	114·8	36·8
84	183·2	67·2	45	113	36
83	181·4	66·4	44	111·2	35·2
82	179·6	65·6	43	109·4	34·4
81	177·8	64·8	42	107·6	33·6
80	176	64	41	105·8	32·8
79	174·2	63·2	40	104	32
78	172·4	62·4	39	102·2	31·2
77	170·6	61·6	38	100·4	30·4
76	168·8	60·8	37	98·6	29·6
75	167	60	36	96·8	28·8
74	165·2	59·2	35	95	28
73	163·4	58·4	34	93·2	27·2
72	161·6	57·6	33	91·4	26·4
71	159·8	56·8	32	89·6	25·6
70	158	56	31	87·8	24·8
69	156·2	55·2	30	86	24
68	154·4	54·4	29	84·2	23·2
67	152·6	53·6	28	82·4	22·4
66	150·8	52·8	27	80·6	21·6
65	149	52	26	78·8	20·8
64	147·2	51·2	25	77	20
63	145·4	50·4	24	75·2	19·2
62	143·6	49·6	23	73·4	18·4

TABLES OF COMPARISON OF THERMOMETRIC SCALES
—continued.

Centi-grade.	Fahrenheit.	Réaumur.	Centi-grade.	Fahrenheit.	Réaumur.
22	71·6	17·6	14	6·8	11·2
21	69·8	16·8	15	5	12
20	68	16	16	3·2	12·8
19	66·2	15·2	17	1·4	13·6
18	64·4	14·4	18	Zero	14·4
17	62·6	13·6	19	— 2·2	15·2
16	60·8	12·8	20	4	16
15	59	12	21	5·8	16·8
14	57·2	11·2	22	7·6	17·6
13	55·4	10·4	23	9·4	18·4
12	53·6	9·6	24	11·2	19·2
11	51·8	8·8	25	13	20
10	50	8	26	14·8	20·8
9	48·2	7·2	27	16·6	21·6
8	46·4	6·4	28	18·4	22·4
7	44·6	5·6	29	20·2	23·2
6	42·8	4·8	30	22	24
5	41	4	31	23·8	24·8
4	39·2	3·2	32	25·6	25·6
3	37·4	2·4	33	27·4	26·4
2	35·6	1·6	34	29·2	27·2
1	33·8	0·8	35	31	28
Zero	32	Zero	36	32·8	28·8
— 1	30·2	— 0·8	37	34·6	29·6
2	28·4	1·6	38	36·4	30·4
3	26·6	2·4	39	38·2	31·2
4	24·8	3·2	40	40	32
5	23	4	41	41·8	32·8
6	21·2	4·8	42	43·6	33·6
7	19·4	5·6	43	45·4	34·4
8	17·6	6·4	44	47·2	35·2
9	15·8	7·2	45	49	36
10	14	8	46	50·8	36·8
11	12·2	8·8	47	52·6	37·6
12	10·4	9·6	48	54·4	38·4
13	8·6	10·4	49	56·2	39·2

TABLES OF COMPARISON OF THERMOMETRIC SCALES
— *continued.*

Fahrenheit.	Centigrade.	Réaumur.	Fahrenheit.	Centigrade.	Réaumur.
+212	+100	+80	+170	+76·67	+61·33
211	99·44	79·56	169	76·11	60·89
210	98·89	79·11	168	75·55	60·44
209	98·33	78·67	167	75	60
208	97·78	78·22	166	74·44	59·56
207	97·22	77·78	165	73·89	59·11
206	96·67	77·33	164	73·33	58·67
205	96·11	76·89	163	72·78	58·22
204	95·55	76·44	162	72·22	57·78
203	95	76	161	71·67	57·33
202	94·44	75·56	160	71·11	56·89
201	93·89	75·11	159	70·55	56·44
200	93·33	74·67	158	70	56
199	92·78	74·22	157	69·44	55·56
198	92·22	73·78	156	68·89	55·11
197	91·67	73·33	155	68·33	54·67
196	91·11	72·89	154	67·78	54·22
195	90·55	72·44	153	67·22	53·78
194	90·00	72	152	66·67	53·33
193	89·44	71·56	151	66·11	52·89
192	88·89	71·11	150	65·55	52·44
191	88·33	70·67	149	65	52
190	87·78	70·22	148	64·44	51·56
189	87·22	69·78	147	63·89	51·11
188	86·67	69·33	146	63·33	50·67
187	86·11	68·89	145	62·78	50·22
186	85·55	68·44	144	62·22	49·78
185	85	68	143	61·67	49·33
184	84·44	67·56	142	61·11	48·89
183	83·89	67·11	141	60·55	48·44
182	83·33	66·67	140	60	48
181	82·78	66·22	139	59·44	47·56
180	82·22	65·78	138	58·89	47·11
179	81·67	65·33	137	58·33	46·67
178	81·11	64·89	136	57·78	46·22
177	80·55	64·44	135	57·22	45·78
176	80	64	134	56·67	45·33
175	79·44	63·56	133	56·11	44·89
174	78·89	63·11	132	55·55	44·44
173	78·33	62·67	131	55	44
172	77·78	62·22	130	54·44	43·56
171	77·22	61·78	129	53·89	43·11

TABLES OF COMPARISON OF THERMOMETRIC SCALES
—continued.

Fahrenheit.	Centigrade.	Réaumur.	Fahrenheit.	Centigrade.	Réaumur.
+128	+53·33	+42·67	+86	+30	+24
127	52·78	42·22	85	29·44	23·56
126	52·22	41·78	84	28·89	23·11
125	51·67	41·33	83	28·33	22·67
124	51·11	40·89	82	27·78	22·22
123	50·55	40·44	81	27·22	21·78
122	50	40	80	26·67	21·33
121	49·44	39·56	79	26·11	20·89
120	48·89	39·11	78	25·55	20·44
119	48·33	38·67	77	25	20
118	47·78	38·22	76	24·44	19·56
117	47·22	37·78	75	23·89	19·11
116	46·67	37·33	74	23·33	18·67
115	46·11	36·89	73	22·78	18·22
114	45·55	36·44	72	22·22	17·78
113	45	36	71	21·67	17·33
112	44·44	35·56	70	21·11	16·89
111	43·89	35·11	69	20·55	16·44
110	43·33	34·67	68	20	16
109	42·78	34·22	67	19·44	15·56
108	42·22	33·78	66	18·89	15·11
107	41·67	33·33	65	18·33	14·67
106	41·11	32·89	64	17·78	14·22
105	40·55	32·44	63	17·22	13·78
104	40	32	62	16·67	13·33
103	39·44	31·56	61	16·11	12·89
102	38·89	31·11	60	15·55	12·44
101	38·33	30·67	59	15	12
100	37·78	30·22	58	14·44	11·56
99	37·22	29·78	57	13·89	11·11
98	36·67	29·33	56	13·33	10·67
97	36·11	28·89	55	12·78	10·22
96	35·55	28·44	54	12·22	9·78
95	35	28	53	11·67	9·33
94	34·44	27·56	52	11·11	8·89
93	33·89	27·11	51	10·55	8·44
92	33·33	26·67	50	10	8
91	32·78	26·22	49	9·44	7·56
90	32·22	25·78	48	8·89	7·11
89	31·67	25·33	47	8·33	6·67
88	31·11	24·89	46	7·78	6·22
87	30·55	24·44	45	7·22	5·78

TABLES OF COMPARISON OF THERMOMETRIC SCALES
—continued.

Fahrenheit.	Centigrade.	Réaumur.	Fahrenheit.	Centigrade.	Réaumur.
+44	+6·67	+5·33	+1	−17·22	−13·78
43	6·11	4·89	0	17·78	14·22
42	5·55	4·44	−1	18·33	14·67
41	5	4	2	18·89	15·11
40	4·44	3·56	3	19·44	15·56
39	3·89	3·11	4	20	16
38	3·33	2·67	5	20·55	16·44
37	2·78	2·22	6	21·11	16·89
36	2·22	1·78	7	21·67	17·33
35	1·67	1·33	8	22·22	17·78
34	1·11	0·89	9	22·78	18·22
33	0·55	0·44	10	23·33	18·67
32	0	0	11	23·89	19·11
31	−0·55	−0·44	12	24·44	19·56
30	1·11	0·89	13	25	20
29	1·67	1·33	14	25·55	20·44
28	2·22	1·78	15	26·11	20·89
27	2·78	2·22	16	26·67	21·33
26	3·33	2·67	17	27·22	21·78
25	3·89	3·11	18	27·78	22·22
24	4·44	3·56	19	28·33	22·67
23	5	4	20	28·89	23·11
22	5·55	4·44	21	29·44	23·56
21	6·11	4·89	22	30	24
20	6·67	5·33	23	30·55	24·44
19	7·22	5·78	24	31·11	24·89
18	7·78	6·22	25	31·67	25·33
17	8·33	6·67	26	32·22	25·78
16	8·89	7·11	27	32·78	26·22
15	9·44	7·56	28	33·33	26·67
14	10	8	29	33·89	27·11
13	10·55	8·44	30	34·44	27·56
12	11·11	8·89	31	35	28
11	11·67	9·33	32	35·55	28·44
10	12·22	9·78	33	36·11	28·89
9	12·78	10·22	34	36·67	29·33
8	13·33	10·67	35	37·22	29·78
7	13·89	11·11	36	37·78	30·22
6	14·44	11·56	37	38·33	30·67
5	15	12	38	38·89	31·11
4	15·55	12·44	39	39·44	31·56
3	16·11	12·89	40	40	32
2	16·67	13·33			

COMPARISON OF FAHRENHEIT AND CENTIGRADE SCALES FOR TEMPERATURES OVER 100° F.

F.	C.	F.	C.	F.	C.
100	55·56	1,300	722·22	2,500	1388·89
200	111·11	1,400	777·78	2,600	1444·44
300	166·67	1,500	833·33	2,700	1500·00
400	222·22	1,600	888·89	2,800	1555·55
500	277·78	1,700	944·44	2,900	1611·11
600	333·33	1,800	1000·00	3,000	1666·66
700	388·89	1,900	1055·56	3,100	1722·22
800	444·44	2,000	1111·11	3,200	1777·78
900	500·00	2,100	1166·67	3,300	1833·33
1,000	555·56	2,200	1222·22	3,400	1888·89
1,100	611·11	2,300	1277·78	3,500	1944·44
1,200	666·66	2,400	1333·33	3,600	2000·00

The number representing the ° F. is written in terms of hundreds and a remainder. The ° C. corresponding to this remainder is obtained from the previous table, and is *added to* the number given in this table.

WEIGHTS AND MEASURES.

British Weights and Measures.

1. Apothecaries Weight.

20 Grains = 1 Scruple.
3 Scruples = 1 Drachm = 60 Grains.
8 Drachms = 1 Ounce = 480 Grains.

2. Avoirdupois Weight.

437½ Grains = 1 Ounce.
16 Ounces = 1 Pound = 7000 Grains.
¼ ounce = 109 grains; ½ ounce = 219 grains; ¾ ounce = 328 grains.

3. Fluid Measure.

60 Minims = 1 Drachm.
8 Drachms = 1 Ounce = 480 Minims.
20 Ounces = 1 Pint = 160 Drachms = 9600 Minims.
2 Pints = 1 Quart = 40 Ounces = 320 Drachms.
4 Quarts = 1 Gallon = 160 Ounces = 1280 Drachms.

1 fluid ounce of water weighs 437½ grains, therefore every minim weighs 0·91 grains.

METRIC WEIGHTS AND MEASURES.

The unit of weight is the gramme, written "gm." ; the sub-divisions are the "deci-" (1/10th), "centi-" (1/100th), and "milligramme" (1/1000th) ; the multiples are the "deka-" (10 gm.) and "hectogramme" (100 gm.), but in practice it is usual to use the term 0·1 or 0·01 and 10 or 100 grammes, and the abbreviation "kilo." for 1,000 gms.

The following are the equivalents of Metric Weights and Measures in terms of Imperial Weights and Measures :—

LINEAR MEASURE.

1 Millimetre (mm.) (1/1000th M.) .	=	0·03937 inch.
1 Centimetre (1/100th M.) . .	=	0·3937 "
1 Metre (M.)	=	39·370113 inches. 3·280843 feet. 1·0936143 yards.
Kilometre (1000 M.) . . .	=	0·62137 mile.

SQUARE MEASURE.

1 Square Centimetre . . .	=	0·155 square inch.
1 Square Metre (100 square decimetres)	=	10·7639 square feet. 1·196 square yards.

WEIGHT.

		Avoirdupois.
1 Milligramme (1/1000th gm.) .	=	0·015 grain.
1 Gramme (1 gm.)	=	15·432 "
1 Kilogramme (1000 gm.) . .	=	2·2046223 lbs. or 35·273957 ozs.

CONVERSION OF GRAINS, OZS., LBS., QRS., CWTS., INTO KILOGRAMMES.

7·716175 grains = 0·5 grammes.
15·432350 " = 1·0 "
154·323500 " = 10·0 "
437½ grains = 1 oz. = 28$\frac{3}{10}$ grammes.
16 ozs. = 1 lb. = 453·59 "
28 lb. = 1 qr. = 12 kilos. 712 grammes.
4 qrs. = 1 cwt. = 112 lbs. = 50 kilos. 803 grammes.
20 cwt. = 1 ton = 1016·06 kilos.

1 oz. = 437½ grs.	= 28·3502 gms.	9 oz. = 3937½ grs.	= 255·1457 gms.
2 " = 875 "	= 56·6991 "	10 " = 4375 "	= 283·4952 "
3 " = 1312½ "	= 85·0486 "	11 " = 4812½ "	= 311·8448 "
4 " = 1750 "	= 113·3981 "	12 " = 5250 "	= 340·1942 "
5 " = 2187½ "	= 141·7482 "	13 " = 5687½ "	= 368·5438 "
6 " = 2625 "	= 170·0972 "	14 " = 6125 "	= 396·8933 "
7 " = 3062½ "	= 198·4466 "	15 " = 6562½ "	= 425·2428 "
8 " = 3500 "	= 226·7962 "	16 " = 7000 "	= 453·5923 "

CONVERSION OF POUNDS INTO KILOGRAMMES.

lbs.		Ko.
1	=	0·453
2	=	0·906
3	=	1·359
4	=	1·812
5	=	2·265
6	=	2·719
7	=	3·172
8	=	3·625
9	=	4·078
10	=	4·531
11	=	4·984
12	=	5·437
13	=	5·890
14	=	6·343
15	=	6·796
16	=	7·249
17	=	7·702
18	=	8·155
19	=	8·608
20	=	9·062
21	=	9·515
22	=	9·968
23	=	10·421
24	=	10·874
25	=	11·327
26	=	11·780
27	=	12·233
28	=	12·686
29	=	13·139
30	=	13·594

lbs.		Ko.
31	=	14·047
32	=	14·500
33	=	14·953
34	=	15·406
35	=	15·859
36	=	16·312
37	=	16·765
38	=	17·218
39	=	17·671
40	=	18·125
41	=	18·578
42	=	19·031
43	=	19·484
44	=	19·937
45	=	20·390
46	=	20·843
47	=	21·296
48	=	21·749
49	=	22·202
50	=	22·656
60	=	27·187
70	=	31·719
80	=	36·250
90	=	40·781
100	=	45·302
200	=	90·625
300	=	135·937
400	=	181·250
500	=	226·562

CONVERSION OF GRAMMES INTO GRAINS AND OUNCES (AVOIRDUPOIS).

Gms.	Ozs.	Grs.	Gms.	Ozs.	Grs.	Gms.	Ozs.	Grs.
0·1		1·5	16	½	28·1	130	4½	37
0·2		3·1	17	½	43·5	140	4¾	82
0·3		4·6	18	½	59·0	150	5¼	118
0·4		6·2	19	½	74·4	160	5½	61
0·5		7·7	20	½	89·8	170	6	0
0·6		9·1	25	¾	57·0	175	6	76
0·7		10·8	30	1	25	180	6¼	44
0·8		12·4	35	1	103	190	6½	88
0·9		13·9	40	1¼	71	200	7	24
1		15·43	45	1½	38	250	8¾	32
2		30·9	50	1¾	6	300	10½	31
3		46·3	55	1¾	83	350	12¼	41
4		61·7	60	2	51	400	14	50
5		77·2	65	2¼	19	450	15¾	52
6		92·6	70	2¼	94	500	17½	61
7		108·0	75	2½	64	550	19¼	66
8	¼	14·1	80	2¾	32	600	21	70
9	¼	29·5	85	3	0	650	22¾	72
10	¼	44·9	90	3	76	700	24½	81
11	¼	60·4	95	3¼	44	750	26¼	91
12	¼	75·8	100	3½	11	800	28	95
13	¼	91·2	110	3¾	56	850	29¾	102
14	¼	106·7	120	4	102	900	31½	106
15	½	12·7	125	4¼	70	1,000	35¼	11

Note.—In the above table the British equivalents are given in the form most convenient for actual work, viz., in even ounces and quarter ounces, with odd grains over. If calculations need to be made, the following figures giving the equivalents of ounces and quarter ounces in grains will be found useful :—

¼ oz. = 109 grs.	1¾ oz. = 765 grs.	3¼ ozs. = 1,421 grs.	4¾ ozs. = 2,078 grs.
½ ,, = 219 ,,	2 ,, = 875 ,,	3½ ,, = 1,531 ,,	5¼ ,, = 2,296 ,,
¾ ,, = 328 ,,	2¼ ,, = 984 ,,	3¾ ,, = 1,640 ,,	5½ ,, = 2,406 ,,
1 ,, = 437 ,,	2½ ,, = 1,094 ,,	4 ,, = 1,750 ,,	6 ,, = 2,625 ,,
1¼ ,, = 546 ,,	2¾ ,, = 1,203 ,,	4¼ ,, = 1,859 ,,	6¼ ,, = 2,734 ,,
1½ ,, = 656 ,,	3 ,, = 1,312 ,,	4½ ,, = 1,969 ,,	6½ ,, = 2,844 ,,

CONVERSION OF KILOGRAMMES INTO POUNDS.

Kilogrammes into	Cwts.	Qrs.	Lbs.	Oz.	Approximate conversion into pounds.
1	0	0	2	$3\frac{1}{4}$	$2\frac{1}{5}$
2	0	0	4	$6\frac{1}{2}$	$4\frac{2}{5}$
3	0	0	6	$9\frac{3}{4}$	$6\frac{3}{5}$
4	0	0	8	13	$8\frac{7}{8}$
5	0	0	11	$0\frac{1}{4}$	11
6	0	0	13	$3\frac{1}{2}$	$13\frac{1}{5}$
7	0	0	15	7	$15\frac{1}{2}$
8	0	0	17	$10\frac{1}{4}$	$17\frac{5}{8}$
9	0	0	19	$13\frac{1}{2}$	$19\frac{7}{8}$
10	0	0	22	$0\frac{3}{4}$	$22\frac{1}{8}$
20	0	1	16	$1\frac{1}{2}$	$44\frac{1}{4}$
30	0	2	10	$2\frac{1}{2}$	$66\frac{3}{8}$
40	0	3	4	3	88
50	0	3	26	$3\frac{3}{4}$	$110\frac{1}{4}$
60	1	0	20	$4\frac{1}{2}$	132
70	1	1	14	$5\frac{1}{4}$	154
80	1	2	8	6	176
90	1	3	2	$6\frac{1}{2}$	198
100	1	3	24	7	$220\frac{1}{2}$
200	3	3	20	15	441
300	5	3	17	6	$661\frac{1}{2}$
400	7	3	13	14	882
500	9	3	10	5	$1102\frac{1}{2}$

FLUID MEASURES.

Pints Quarts Gallons Litres

2 = 1

8 = 4 = 1 = 4·543

1 Imp. gallon = 8 pints = 32 gills = 160 oz. = 4 kil. 540 grms.

1 „ = 4 „ = 20 „ = 0 „ 567 „

In English works 2 noggins = 1 gill. (10 fl. oz.)

2 gills = 1 pint.

In Scotch works 4 gills = 1 pint.

(5 fl. oz.) (20 fl. oz.)

1 U.S. gallon = 3·785 litres.

1 Imp. „ = 4·5436 „ = 4543 cubic centimetres.

1 „ water = 10 lbs. Engl.

1000 Imp. gallons = 10015 lbs. Engl. = 4543 kilo.

210 „ water = 1 ton = 35·943 cubic feet.

1 „ „ = 227¼ cubic inches = 0·16 cubic feet = 10 lbs.

1 Imp. pipe = 572·48 litres.

1 U. S. „ = 476·94 „

1 litre = 100 centilitres = 1 cubic decimetre = 1·76 Imp. [pint = 2·114 U. S. pints.

1 hectolitre = 10 decalitres = 100 litres.

1 pint	=	34·65	cubic inches	=	1¼ lbs.	=	·568 litres.
1 quart	=	69·31	„	=	2½ „	=	1·136 „
1 gallon	=	277·25	„	=	10 „	=	4·543 „
1 bushel	=	2218	„	=	80 „	=	36·348 „
1 cubic inch				=	·0361 „	=	16·386 c.cs.
1 „ foot	=	1728	„	=	62·5 „	=	28·315 litres.

1 „ „ = 62·5 gallons.

1 „ yard = 168·26 „

1 ton of water = 35·76 cubic feet = 224 gallons.

CONVERSION OF GALLONS INTO LITRES.

Imp. galls.		litres.	Imp. galls.		litres.
1	=	4·5434	40	=	181·744
2	=	9·0872	50	=	227·180
3	=	13·6308	60	=	272·616
4	=	18·1748	70	=	318·052
5	=	22·718	80	=	363·488
6	=	27·2616	90	=	408·924
7	=	31·8052	100	=	454·360
8	=	36·3488	200	=	908·720
9	=	40·8924	300	=	1363·080
10	=	45·436	400	=	1817·440
20	=	90·872	500	=	2271·800
30	=	136·308	1000	=	4543·600

CONVERSION OF LITRES INTO GALLONS AND PINTS.

Litres		Gallons	Pints	Gills	Litres		Gallons	Pints	Gills
1	=		1	3·0430	15	=	3	2	1·6480
2	=		3	2·0864	16	=	3	4	0·6912
3	=		5	1·1296	17	=	3	5	3·7344
4	=		7	0·1728	18	=	3	7	2·7776
5	=		8	3·2160	19	=	4	1	1·8208
6	=	1	2	2·2592	20	=	4	3	0·8640
7	=	1	4	1·3024	21	=	4	4	3·9072
8	=	1	6	0·3456	22	=	4	6	2·9504
9	=	1	7	3·3888	23	=	5	0	1·9936
10	=	2	1	2·4320	24	=	5	2	1·0368
11	=	2	3	1·4752	25	=	5	4	0·0800
12	=	2	5	0·5184	50	=	11	0	0·1600
13	=	2	6	3·5616	75	=	16	4	0·2400
14	=	3	0	2·6048	100	=	22	0	0·3200

A TABLE OF ATOMIC WEIGHTS OF THE CHEMICAL ELEMENTS.

Name.	Symbol.	Atomic Weight in Round Numbers.	Accurate Atomic Weight.
Aluminium	Al	27	27·1
Antimony	Sb	120	120·2
Argon	A	40	39·9
Arsenic	As	75	75·0
Barium	Ba	137	137·43
Beryllium	Be = Gl	9·1	9·1
Bismuth	Bi	208	208·0
Boron	B	11	11·00
Bromine	Br	80	79·96
Cadmium	Cd	112	112·4
Cæsium	Cs	133	132·9
Calcium	Ca	40	40·1
Carbon	C	12	12·0
Cerium	Ce	140	140·25
Chlorine	Cl	35·5	35·451
Chromium	Cr	52	52·11
Cobalt	Co	59	59·00
Copper	Cu	63·5	63·60

A TABLE OF ATOMIC WEIGHTS OF THE CHEMICAL ELEMENTS—*continued.*

Name.	Symbol.	Atomic Weight in Round Numbers.	Accurate Atomic Weight.
Erbium	Er	166	166·0
Fluorine	F	19	19·0
Gadolinium	Gd	156	156·01
Gallium	Ga	70	70·0
Germanium	Ge	72·5	72·5
Gold	Au	197	197·2
Helium	He	4	4·0
Hydrogen	H	1	1·008
Indium	In	115	115·0
Iodine	I	127	126·97
Iridium	Ir	193	193·0
Iron	Fe	56	55·9
Lanthanum	La	139	138·9
Lead	Pb	207	206·92
Lithium	Li	7	7·03
Magnesium	Mg	24	24·36
Manganese	Mn	55	55·0
Mercury	Hg	200	200·0
Molybdenum	Mo	96	96·0
Neodymium	Nd	144	143·6
Nickel	Ni	59	58·70
Niobium	Nb = Cb	94	94·0
Nitrogen	N	14	14·04
Osmium	Os	191	191·0
Oxygen (Standard)	O	16	16·0
Palladium	Pd	106	106·5
Phosphorus	P	31	31·0

A TABLE OF ATOMIC WEIGHTS OF THE CHEMICAL ELEMENTS—*continued.*

Name.	Symbol.	Atomic Weight in Round Numbers.	Accurate Atomic Weight.
Platinum	Pt	195	194·8
Potassium	K	39	39·15
Praseodymium	Pr	141	140·5
Rhodium	Rh	103	103·0
Rubidium	Rb	85	85·5
Ruthenium	Ru	102	101·7
Samarium	Sm	150	150·3
Scandium	Sc	44	44·1
Selenium	Se	79	79·2
Silicon	Si	28	28·4
Silver	Ag	108	107·93
Sodium	Na	23	23·05
Strontium	Sr	87·5	87·6
Sulphur	S	32	32·06
Tantalum	Ta	183	183·0
Tellurium	Te	128	127·6
Terbium	Tb	160	160·0
Thallium	Tl	204	204·1
Thorium	Th	233	232·5
Thulium	Tu	171	171·0
Tin	Sn	119	119·0
Titanium	Ti	48	48·1
Tungsten	W	184	184·0
Uranium	U	238·5	238·5
Vanadium	V	51	51·4
Ytterbium	Yb	173	173·0
Yttrium	Yt	89	89·0
Zinc	Zn	65·5	65·4
Zirconium	Zr	91	90·6

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